Fishery Data Series No. 05-13

Falls, Gut Bay, and Kutlaku Lakes Subsistence Sockeye Salmon Project 2003 Annual Report and 2001–2003 Final Report

by

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and

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February 2005

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA REPORT NO. 05-13

FALLS, GUT BAY, AND KUTLAKU LAKES SUBSISTENCE SOCKEYE SALMON PROJECT 2003 ANNUAL REPORT AND 2001–2003 FINAL REPORT

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The Federal Subsistence Board, managed by U.S. Fish and Wildlife Service Office of Subsistence Management, approved the Falls Lake Sockeye Salmon Stock Assessment Project (Study Number FIS00-044) and the Gut, Kook, and Hoktaheen Sockeye Salmon Stock Assessment Project (Study Number FIS01-125). The projects were funded by the U.S. Forest Service, and are cooperative projects between the U.S. Forest Service (USFS), the Alaska Department of Fish and Game (ADF&G), and the Organized Village of Kake. This annual report partially fulfills contract obligations for Sikes Act Contract (53-0109-2-6110, 53-0109-2-61200, and 43-0109-0-0174). Project funding for the 2003 season was also provided through ADF&G by the Southeast Sustainable Salmon Fund (SSSF Project No. 45247).

The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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ABSTRACT

Since the early 1990s there has been a sharp increase in the reported subsistence harvest at Falls Lake. ADF&G managers and the Organized Village of Kake questioned whether sockeye escapements into Falls Lake were adequate. However, in 2003, we estimated about 5,700 sockeye spawners in Falls Lake, a large increase from 1,100 in 2002 and 2,700 in 2001. The total marine terminal area harvest of 2,700 sockeye salmon in 2003 was the largest on record. Our results indicate total sockeye returns to Falls Lake may have been higher in 2001–2003 than returns in the 1980s, but escapement has remained about the same because more fish were harvested. Sockeye fry populations and zooplankton biomass were very low in 2001–2003 in this oligotrophic lake.

A research study in Gut Bay Lake was discontinued in 2003, but boat surveys conducted in the lake in 2001–2002 showed small, dispersed spawning populations around the shore of the lake. Subsistence fishers consistently report harvests of about 400 sockeye salmon annually from Gut Bay. We estimated sockeye salmon fry populations of 50,000–70,000 in 2001 and 2002, and very low zooplankton populations in those years. We recommend installing a weir on this system to get an accurate estimate of sockeye escapement.

In Kutlaku Lake, we generated a very approximate estimate of total escapement of about 8,500 sockeye salmon. In 2002, we estimated approximately 10,000 sockeye salmon spawners using the same methods. Populations of 100,000 fry and 115,000 fry were estimated in 2001 and 2002. Zooplankton biomass was moderate in 2001–2003.

Key words: Sockeye salmon, *Oncorhynchus nerka*, subsistence, Falls Lake, Gut Bay Lake, Kutlaku Lake, Kake, escapement, fry, smolt, mark-recapture, zooplankton

CHAPTER 1 – 2003 ANNUAL REPORT

INTRODUCTION

Falls Lake (ADF&G stream no. 109-20-013/014), Gut Bay Lake (ADF&G stream no. 109-20-007/008), and Kutlaku Lake (ADF&G stream no. 109-52-035) produce sockeye salmon (*Oncorhynchus nerka*) runs traditionally and currently important to subsistence users from the village of Kake (Figure 1). In the Falls, Gut Bay, and Kutlaku Lakes Subsistence Sockeye Salmon Project (which we will subsequently refer to as the "Kake Sockeye Project" or simply "the project") we studied demographics of sockeye salmon that return to these three systems; our purpose is to sustain escapements and provide subsistence harvest opportunities in these systems. Initiated in 2001, this project is operated cooperatively between ADF&G, the Organized Village of Kake (OVK), and the U.S. Forest Service. Data collection began in the 2001 field season.

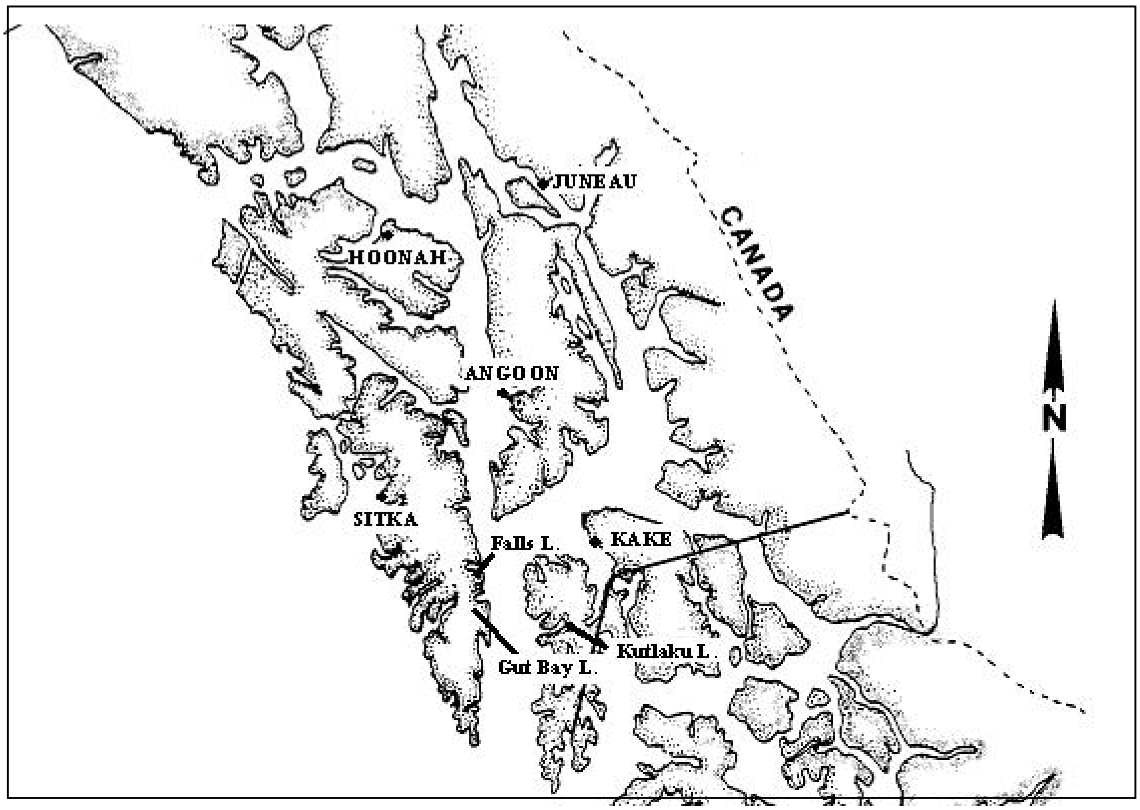

Figure 1.–Map of Southeast Alaska showing location of Falls, Gut Bay, and Kutlaku Lakes, and the village of Kake.

The significance of sockeye salmon streams to indigenous peoples in a wide-ranging area around the present-day village of Kake is well-documented (Goldschmidt *et al.* 1998; and Bosworth 1990) and can be attested to by many people who currently live in or grew up in Kake (M. Jackson OVK, personal communication 2001). Old village sites in the Bay of Pillars area and small settlements or fishing camps in proximity to the sockeye streams at Falls and Gut Bay provide physical evidence for a long history of use and dependence on sockeye salmon from these streams.

Kake people, who until the early 1900s were spread out among many small villages on Kupreanof, Kuiu, Baranof, and Admiralty Islands and the mainland, also participated in commercial salmon fisheries in this area since their inception in the late 1800s. Work in the commercial fisheries and fish processing supplemented the subsistence harvest of salmon and other foods. Not until current fishery regulations were established after Alaska Statehood in 1960 did the two modes of livelihood for villagers begin to be regarded as separate. Recent changes in the commercial fisheries forced many small operators in Kake out of business, who also lost convenient access to distant subsistence fishing and hunting areas, resulting in increased dependence on subsistence fishing to fulfill residents' needs for salmon (Firman and Bosworth 1990; ADF&G Div. of Subsistence, Community Profile Database 2003; Conitz and Cartwright 2002, 2003).

The ADF&G Division of Commercial Fisheries compiles effort and harvest data reported by permit-holders in its regional database. In the past decade, reported subsistence sockeye salmon harvest and effort have increased more than four-fold at Falls Lake, remained about the same, on average, at Gut Bay, and declined at the Bay of Pillars/Kutlaku (Appendix A). Many factors may contribute to these trends, including improved reporting in recent years, a decrease in the amount of subsistence salmon taken in the commercial fisheries, and the use of larger outboard motors to access the areas. One important objective of this project is to obtain on-site effort and harvest data at Falls Lake, and compare to that reported on permits. No on-site harvest assessments have been undertaken at Gut Bay or Kutlaku Lakes.

Commercial fisheries were established in Chatham Straits by 1889. In the early years, sockeye salmon were targeted in the terminal areas, and many of the productive runs were severely depleted by the early 1920s (Rich and Ball 1933; Conitz *et al.* 2002, Conitz and Cartwright 2002). Since conservation closures were implemented starting in 1925, there has been little or no commercial salmon fishing in the terminal areas of the sockeye-producing systems in lower Chatham Strait. Outside of the terminal areas, however, the present-day purse seine fleet is now the largest harvester of sockeye salmon in Chatham Strait. Commercial fishery data from recent years show a dramatic increase in the total sockeye harvest between 1970 and 1999 in the main sub-districts on the west (109–10, -20) and east (109-51, –61) sides of Chatham Strait (Figure 2); this trend has continued since 2000 on the east side of lower Chatham but not on the west side. In all lower Chatham sub-districts combined, the average annual sockeye harvest in 2000–2003 is nearly double the overall average harvest from 1970–2003 (Appendix B). The great increase is attributed to high hatchery chum production, resulting in increased commercial fishing effort and harvest overall (Larson 2001).

Subsistence users from Kake expressed concern about the recent increase in charter fishing and sport fishing lodges in the vicinity of subsistence fishing areas around Kake. Some Kake fishermen have reported charter vessels anchoring vessels in productive fishing locations and interfering with the normal subsistence fishing activities (Larson 2001). There are few or no estimates of sport and charter effort and harvest in specific areas (ADF&G Div. of Sport Fish database 2003; Conitz and Cartwright 2003). However, sport and charter fisheries generally target species other than sockeye salmon.

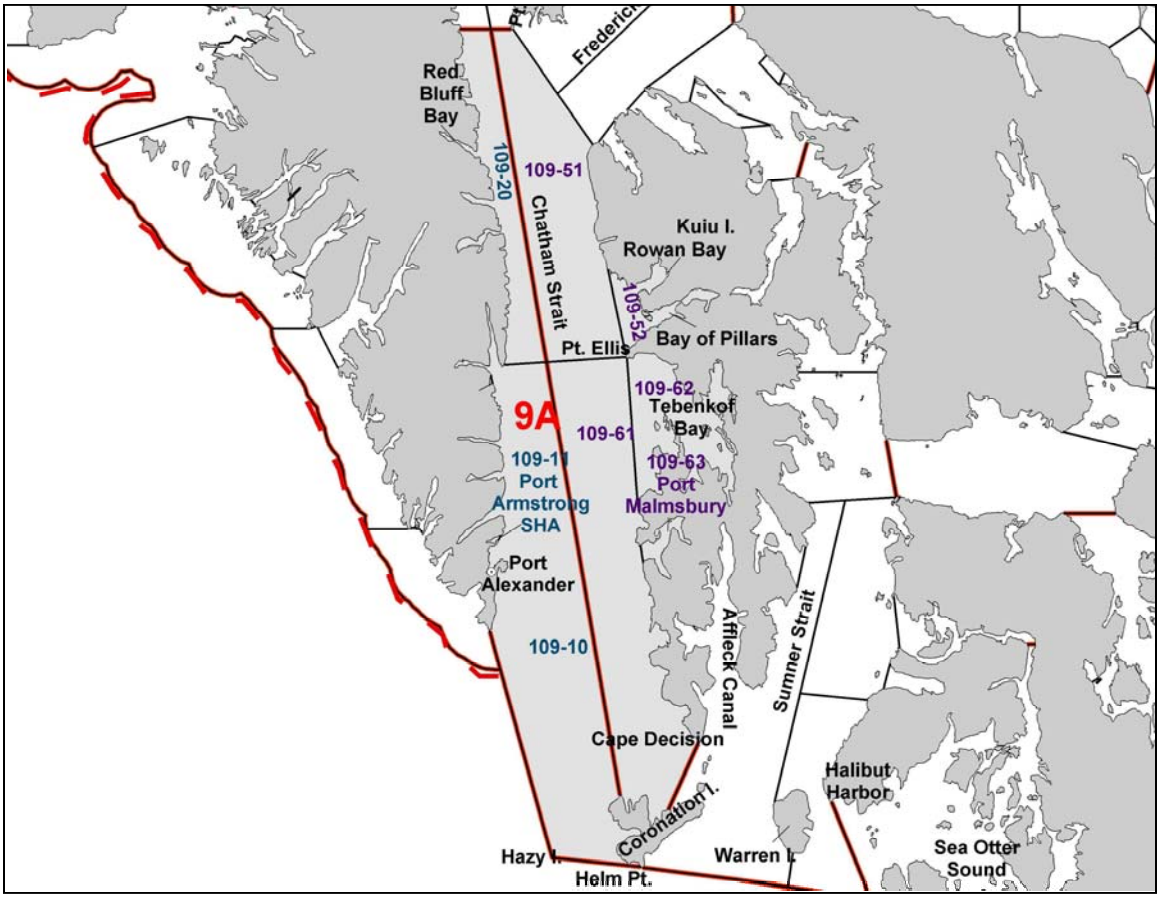

Figure 2.–Commercial fishing districts in southern Chatham Strait, including areas adjacent to Falls Lake (109–20-13), Gut Bay (109-20-7) and the Bay of Pillars (109–51, –52).

Falls Creek, Gut Bay, and Bay of Pillars (Kutlaku) have federal and state Customary and Traditional (C&T) use designation. Federal subsistence regulations currently state that, "Only Federally qualified subsistence users may harvest sockeye salmon in streams draining into Falls Lake, Gut Bay, or Pillar Bay." (Federal Register 2001) The Alaska Department of Fish and Game is seeking for a second time to rescind this regulation for Kutlaku/Pillar Bay, based on insufficient evidence of a conservation concern (D. Fleming ADF&G, personal communication 2004).

Previous salmon stock and biological assessments of the Falls, Gut Bay, and Kutlaku Lake systems included a lake fertilization study at Falls Lake in the 1980s, combined with construction of a fish ladder in the lake outlet in 1986, escapement age-sex-length sampling in Kutlaku Lake since 1982, and occasional aerial surveys of all three systems (Conitz and Cartwright 2002, 2003; Conitz et al. 2002). Falls Lake is the only system of the three for which we have any reliable information, prior to this project, on sockeye escapements and lake productivity, but this information is inconclusive at best (Koenings et al. 1983; Conitz et al. 2002). A field crew counted escapements through a weir in the outlet stream from 1981–1989, with the exception of 1986, when weir operation was disrupted for construction of the fish ladder. Biologists also measured lake physical characteristics and water chemistry parameters, and estimated phytoplankton, zooplankton, and juvenile sockeye populations, both before and during a three-year lake fertilization project. Unfortunately, consistent data collection was not continued following fertilization, so the results of this project are unclear. Similarly, researchers made no rigorous attempt to determine effectiveness of the fish ladder or the proportion of returning salmon using it.

We collected data on sockeye escapements, age and size structure, fry populations, zooplankton prey populations, and water column light and temperature profiles between 2001–2003 in the Falls, Gut Bay, and Kutlaku Lake systems. Additionally, we sampled sockeye smolt emigrating from Falls Lake, and we monitored subsistence and sport harvest in the Falls Lake terminal area. Falls Lake is currently the most popular area for subsistence sockeye fishing among Kake residents, and thus it is the system of greatest interest and concern. We discontinued sampling in Gut Bay Lake in 2003 because floatplane access to the lake was unreliable and dangerous. We added Kutlaku Lake to the project in 2002. We transferred two other study sites (Kook and Hoktaheen Lakes) to other stock assessment projects in cooperation with communities with subsistence fishing histories in those systems. Work performed in 2003 yielded a third year of successful harvest, escapement, and lake productivity estimates at Falls Lake, and completed a two-year baseline of escapement and lake productivity at Kutlaku Lake.

Our goal in collecting sockeye escapement, harvest, and lake rearing habitat information in this project was to begin answering questions about what factors limit sockeye production in each lake. Ultimately, fisheries managers will use this information to make management decisions. For example, if a sockeye system appears to be limited by escapement, then managers can attempt to increase production increasing escapement.

OBJECTIVES

1. Estimate escapement of sockeye salmon into Falls Lake at the weir and on the spawning grounds, with estimated coefficient of variation less than 10% for the weir estimate and less than 15% for the spawning grounds estimate.
2. Estimate the annual sockeye escapement into Kutlaku Lake, using mark-recapture methods and observer counts on the spawning grounds, with estimated coefficient of variation less than 15%. Obtain observer counts of sockeye salmon throughout the spawning season in Gut Bay Lake.
3. Estimate on-grounds subsistence harvest of sockeye salmon in the terminal marine area in front of Falls Lake Creek, with estimated coefficient of variation less than 15%.
4. Estimate the age, length, and sex composition of the sockeye salmon in the escapement at Falls and Kutlaku Lakes, with estimated coefficient of variation less than 5%.
5. At Falls Lake, compare spawning grounds survey/mark-recapture estimates and total estimated escapement of sockeye salmon from the weir and weir mark-recapture study.
6. Estimate productivity of each lake using established ADF&G limnological sampling procedures.
7. Estimate age, sex, and size composition of outmigrant sockeye smolt at Falls Lake, with estimated coefficient of variation less than 10%.

Hydroacoustic and trawl sampling to determine sockeye fry density were dropped in 2003 because of technical difficulties in estimating species apportionment and its variance.

METHODS

STUDY SITES

Falls Lake

Falls Lake (N 56°49.5', W 134°42.2') is located on the east side of Baranof Island just south of Red Bluff Bay, within the central Baranof metasediments subsection (Nowacki et al. 2001). It lies in a steep mountain cirque basin at an elevation of about 20 m, and drains a watershed area of about 1,650 km^2. The continental ice sheets of the Pleistocene Ice Age never overrode the upper elevations of the steep angular mountains in this area, but abundant precipitation formed smaller alpine glaciers, which carved the landscape and persist today. Frequent landslides, debris torrents, and avalanches sweep down the steep slopes, forming colluvial and alluvial fans around the bases of the mountains (Nowacki et al. 2001).

Falls Lake's two main inlet streams, originating in hanging glaciers and steep mountain falls, formed large alluvial fans at their lower ends, supporting productive old-growth spruce forest and willow and alder thickets. The southwest inlet stream is sometimes cloudy with glacial silt; the west-southwest inlet stream is usually clear. The west-southwest inlet stream has been cutting a new channel through the alluvial fan area at least since 2001. Falls Lake has a surface area of about 95 ha, an average depth of 32 m, and a maximum depth of 75 m (Figure 3) and is organically stained. One large main basin in the center of the lake is separated by a shallow sill from a much smaller basin near the outlet. A very short outlet stream plunges over two falls directly into Chatham Strait.

Salmon spawn in the lower reaches of the southernmost of the two main inlet streams, and in and around the mouth of the adjacent stream to the northwest. Both streams have partial or complete migration barriers a short distance upstream from the lake. Sockeye (*Oncorhychus nerka*) and coho (*O. kisutch*) salmon ascend the falls and spawn in the lake or inlet streams. Pink salmon (*O. gorbuscha*) spawn in lower section of the outlet stream, but most eggs are probably washed out because suitable gravel is lacking and flow is periodically high; a very small number of pink salmon ascend the falls. The lake supports resident and anadromous populations of Dolly Varden char (*Salvelinus malma*), as well as sticklebacks (*Gasterosteus aculeatus*), and a few sculpins (*Cottus cognatus*). Coordinates for mark-recapture sampling study areas and limnology sampling stations are listed in Table 1.

Table 1.–Latitude and longitude coordinates for mark-recapture study areas and limnology sampling stations in Falls Lake, determined by Global Positioning System (GPS).

Waypoint ID	Description	Latitude	Longitude
FALLS1	Mouth of main inlet stream	56.819217	-134.708067
FALLS2	East end, beach study area	56.821783	-134.708383
FALLS3	West end, beach study area	56.819367	-134.711967
FALLSA	Limnology Station A	56.823250	-134.694000
FALLSB	Limnology Station B	56.825067	-134.695133

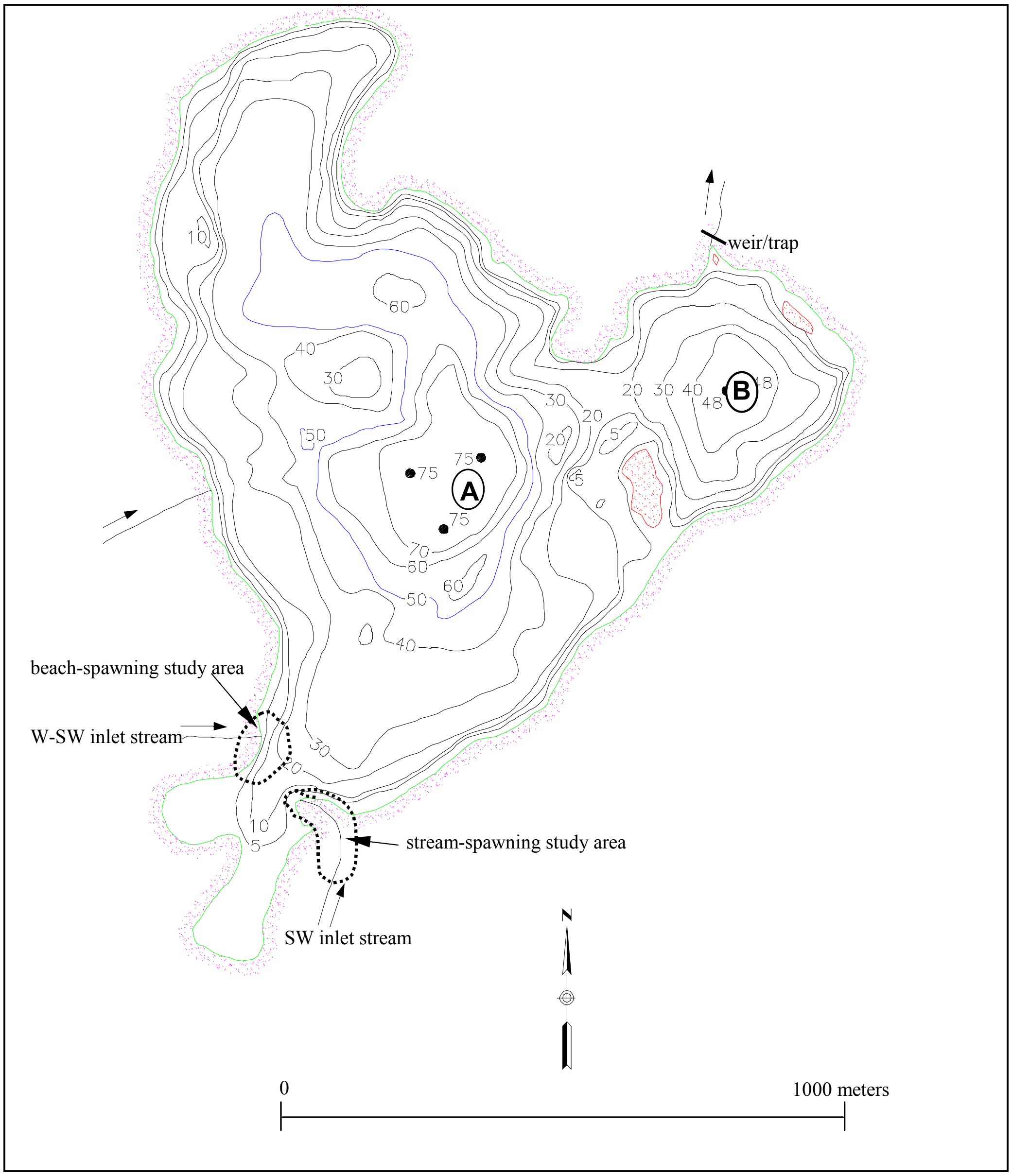

Figure 3.–Bathymetric map of Falls Lake, showing 10 m depth contours, location of weir and trap at top of fishpass on the lake outlet, mark-recapture study areas, and two permanent limnology-sampling stations (A and B).

Kutlaku Lake

Kutlaku Lake (N 56°37.00', W 134°7.54') is located on the west side of Kuiu Island, about 45 km from Kake, and drains into the southeast arm at the head of Bay of Pillars. Kutlaku Lake and the Bay of Pillars are within the Rowan sediments subsection. The rounded mountains in this area were heavily eroded and scoured by continental ice sheets. In some areas, deep residual silty or loamy soils have built up, supporting highly productive hemlock-spruce forests; in other areas, bogs and muskegs formed over glacial till with poorly drained organic soils (Nowacki et al. 2001). Kutlaku Lake is situated at an elevation of about 25 m, and lies in a steep-sided, heavily forested valley, with intermittent patches of windfall, muskeg, and beaver-dammed streams

(Figure 4). The main inlet stream on the south side of the lake has been dammed repeatedly by beavers, forming a large delta area. The lake surface area is about 78 hectares, and the maximum depth is about 22 m. Over half the lake, on the southwest end, is less than 10 m in depth, with a shelf of less than 5 m depth extending out at least 100 m from the shore. The outlet stream exits the northeast corner of the lake through a shallow, marshy area, and flows over a uniform shallow gradient for about 0.7 km into the large intertidal zone at the head of the Bay of Pillars. Sockeye, coho, pink, and chum salmon all spawn in the lake and inlet streams. Anadromous or resident Dolly Varden char and cutthroat trout (*O. clarki*) are present in the lake. Rough-skinned newts (*Taricha granulosa*) are common in the shallow water around the lake outlet. Coordinates for mark-recapture sampling study areas and limnology sampling stations are listed in Table 2.

Table 2.–Latitude and longitude coordinates for mark-recapture study areas and limnology sampling stations in Kutlaku Lake, determined by Global Positioning System (GPS).

Waypoint ID	Description	Latitude	Longitude
KUT1	Study Area 1, mouth of inlet stream	56.608250	-134.136900
KUT2W	Study Area 2, west end	56.612383	-134.129433
KUT2E	Study Area 2, east end	56.614650	-134.127333
KUTA	Limnology Station A	56.614900	-134.128167
KUTB	Limnology Station B	56.614183	-134.129583

SOCKEYE SMOLT RUN TIMING, AGE AND SIZE ESTIMATES

We sampled sockeye and coho smolt during their migration out of Falls Lake in May and June. A small fyke net was placed in the riffle area between the upper and lower falls, on the north bank of the stream. The cod-end of the net was attached to a live box for holding fish for sampling. The fyke net was fished from approximately 8:00 pm to midnight each evening, with a daily target sample of 20–40 smolts. Sampling occurred nightly from May 14 through June 18. Smolts caught in the trap were anaesthetized with a clove oil solution (Anderson et al. 1997), and were weighed to the nearest 0.1 g, measured to the nearest mm, and scale sampled. Smolts were aged by analyzing the scale patterns in the laboratory. The target sample size was 600, enough to distinguish proportions in two or three age classes to a precision of 95% (Thompson 1992, p. 39).

ADULT ESCAPEMENT ESTIMATES

Weir/Trap Mark-Recapture Study

Migrating fish ascending the Falls Lake fish ladder were channeled into a 1.25 m x 1.25 m x 2.5 m box frame trap (Conitz et al. 2002). The crew identified by species, counted, and passed upstream all fish that entered the trap; they also marked all sockeye salmon with finclips for a mark-recapture study to verify the weir count. The crew systematically sampled sockeye salmon daily at the weir for sex, length, and scales; the sampling goal was 600 sockeye salmon distributed through the run.

We operated the weir/trap system continuously from 10 June through 4 September. Historically, most or all spawning sockeye salmon have entered Falls Lake during this period. We did not attempt a full count of coho escapement because we removed the trap before the end of their run.

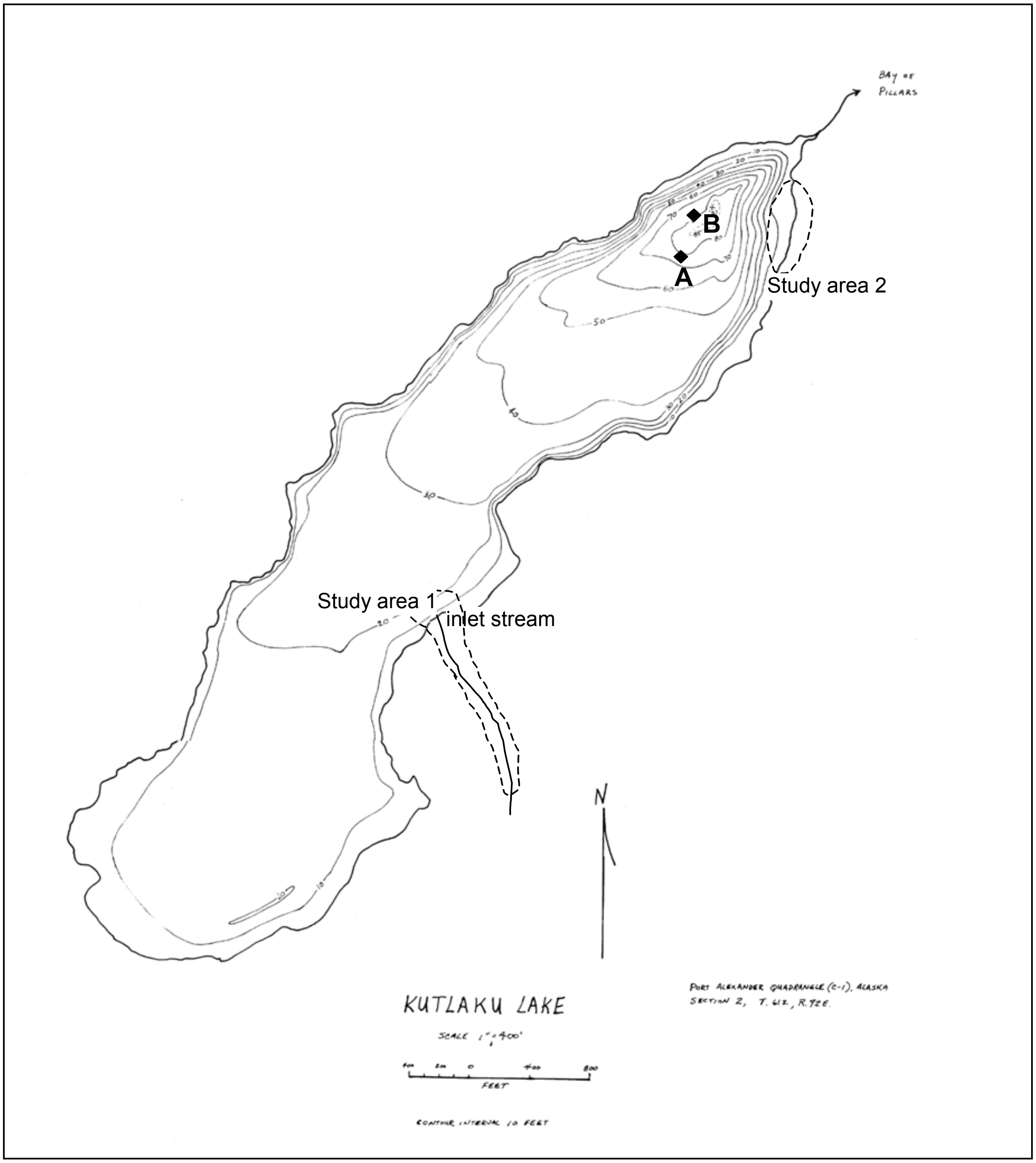

Figure 4.–Topographic map of Kutlaku Lake, showing two permanent limnology sampling stations (A and B) and mark-recapture study areas. Depth contours are in intervals of 10 ft—approximately 3 m.

We used a stratified, two-sample mark-recapture study design to estimate sockeye salmon escapement into Falls Lake (Arnason et al. 1995). The primary mark was an adipose clip, to indicate that the fish was marked and should be checked for a secondary mark. Three marking strata, each representing about one-third of the total run, were identified by the secondary marks shown in Table 3.

Table 3. Marking strata used at the Falls Lake fish ladder, with identifying fin clip and dates used.

Stratum	Fin clip	Dates
1	left axillary	10 June–22 July
2	left ventral	23 July–6 August
3	dorsal	7 August–4 September

Recapture events were conducted on the spawning grounds at approximately bi-weekly intervals throughout the spawning period. Fish were captured and examined for marks in all spawning areas, and marked with a secondary mark to prevent duplicate sampling.

Darroch maximum-likelihood and least-squares, Schaefer population, and "pooled Petersen" estimates were calculated with the Stratified Population Analysis System (SPAS) software (Arnason et al. 1995; for details, refer to http://www.cs.umanitoba.ca/~popan/). Because an estimate of escapement was the only estimate required for our project, SPAS had the advantage of allowing us to pool together some or all of the capture or recapture strata to get a more precise estimate of escapement, possibly at the expense of some bias. If a simple Petersen method is applied to stratified data that have been pooled, the resulting estimate is called the pooled Petersen estimate (Seber 1982). However, the Petersen estimate can be badly biased when the assumptions of equal probability of capture are violated. Briefly stated, the three assumptions of equal probability of capture are: 1) all fish have an equal probability of capture in the first event, 2) all fish have an equal probability of capture in the second event, and 3) fish mix completely between the first and second event. SPAS provides two types of chi-square tests to test whether the assumptions of equal probability of capture could have been violated. The software developers included the test labeled Complete Mixing to test the assumption that probability of movement for fish marked in any first-event stratum to any second-event stratum is not different. This test is equivalent to determining if there is a difference in capture probability for fish in the second event. The software developers included the test labeled Equal Proportions to test the assumption that there is no difference in probability of capture for fish marked in the first event. If the test statistic from either of these tests was not significant (p-value > 0.05), we assumed we met the assumptions of complete mixing and equal capture probability. Even if one of the test statistics was significant (p-value ≤ 0.05), we considered this to be insufficient evidence of a problem with the pooled Petersen estimate, and concluded that partial or complete pooling could still be valid (Arnason et al. 1995). Other criteria were examined, including seeing if pooling produced big changes in the estimate of escapement. If pooling led to a small change, we concluded it was probably safe to pool; however, if pooling led a big change in the estimate, the pooled Petersen estimate may be badly biased. Using the chi-square tests in SPAS as guidelines, we attempted to pool as many strata as possible to increase precision. If both tests were significant (p-value ≤ 0.05), however, we used the less precise Darroch or stratified population estimate.

When use of the pooled Petersen method was warranted, we used the following method to estimate the 95% confidence interval for the escapement estimate, rather than the method provided in the SPAS software. We let K denote the number of fish marked in a random sample of a population of size N. We let C denote the number of fish examined for marks at a later time, and let R denote the number of fish in the second sample with a mark. The estimated number of fish in the entire population, $\hat{N}$, is given by:

$$\hat{N} = \frac{(K+1)(C+1)}{(R+1)} - 1. \tag{1}$$

In this equation, R is a random variable, and is assumed to follow a Poisson, binomial, hypergeometric, or normal distribution, depending on the circumstances of the sampling. When R is large compared with the size of the second sample, C, its distribution can be assumed to be approximately normal (a practical check is to ensure R is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population, p, such that $\hat{p} = \frac{R}{C}$. We used approximate confidence interval bounds around $\hat{p}$ based on the assumption that R follows some sampling distribution. We defined the confidence bounds as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, N^*, were found by taking reciprocals of the confidence interval bounds for p, and multiplying by K. That is, the confidence bounds for the Petersen estimate are given by ($K \cdot 1/a_{0.975}$, $K \cdot 1/a_{0.025}$).

If $\hat{p} \geq 0.1$, and the size of the second sample C is at least the minimum given in Table 4, a 95% confidence interval for p is given by:

$$\hat{p} \pm \left[1.96 \sqrt{\left(1 - \frac{C}{\hat{N}}\right) \cdot \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C} \right] \tag{2}$$

(Seber 1982, eq. 3.4).

Table 4.–Sample size criteria for using Seber's (1982) eq. 3.4 to find 95% confidence interval for a proportion. For given proportion, minimum sizes for the second sample are indicated.

$\hat{p}$ **or 1 -** $\hat{p}$	0.5	0.4	0.3	0.2	0.1
Minimum sample size	30	50	80	200	600

Seber's (1982) eq. 3.4 was also used when $\hat{p} < 0.1$ if $R > 50$. If these criteria were not met, the confidence interval bounds for p were found from Table 41 in Pearson and Hartley (1966).

Adult Population Age and Size Distribution

Scales, matched with sex and length data, were collected from adult sockeye salmon at the Falls Lake weir and on the spawning grounds in Kutlaku Lake to describe the age and size structure of each population. The sampling goal for each lake was 600 fish. At the Falls Lake weir, fish were selected systematically (e.g. every fifth fish) to prevent selection bias, throughout the entire run; at Kutlaku Lake, all unmarked sockeye salmon were sampled on the first day of each sampling trip, until the trip goal of 200 samples was reached. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age and length data were paired for each fish sample. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes 1-year freshwater and 3-years saltwater) (Koo 1962). Brood year tables were compiled by sex and brood year to describe the age structure of the returning adult sockeye salmon population. The length of each fish was measured from mid-eye to tail fork to the nearest millimeter (mm). The proportion p_k of each age-sex group k was estimated as $\hat{p}_k$ by the standard binomial formula, with associated standard error (SE), where n_k is the number of samples in age-sex group k and n is the total number of samples aged:

$$\hat{p}_k = \frac{n_k}{n} \text{ and } SE(\hat{p}_k) = \sqrt{\frac{\hat{p}_k(1-\hat{p}_k)}{n-1}} \tag{3}$$

(Thompson 1992, p. 35–36).

The mean length and associated standard error for age-sex group k were calculated by standard normal methods:

$$\bar{y}_k = \frac{1}{n_k}\sum_{i=1}^{n_k} y_{ki} \text{ and } SE(\bar{y}_k) = \sqrt{\frac{1}{n_k}} * \sqrt{\left(\frac{1}{n_k - 1}\right)\sum_{i=1}^{n_k}(y_{ki} - \bar{y}_i)^2} \tag{4}$$

(Thompson 1992, p. 42–43).

Spawning Grounds Mark-Recapture and Visual Survey

Mark-recapture studies on the spawning grounds were used to provide independent estimates of a portion of sockeye escapement in Falls and Kutlaku Lakes. At Falls Lake, the spawning grounds estimate was compared with the weir-based estimate; at Kutlaku Lake it provided the only estimate of escapement.

We observed distinct patterns of beach spawning and inlet stream spawning in Falls Lake sockeye salmon; we assumed no exchange between these two spawning populations. Therefore, separate series of four mark-recapture events were conducted in the beach spawning and inlet stream spawning areas, accompanied by visual surveys of the lakeshore and inlet streams (Figure 3; Table 1). At Kutlaku Lake, mark-recapture sampling was conducted in the inlet stream that enters the southeast side of the lake (Figure 4; Table 2). One of the several other areas where sockeye salmon spawn along the shoreline of the lake, just south of the lake outlet, was designated as a second study area. Surveys were conducted in the inlet stream and around the lakeshore.

ADF&G biologists modified the methods described in Schwarz et al. (1993) to estimate salmon escapements in beach spawning systems (Cook 1998). Specifically, we used a two-sample Petersen estimate for each trip (J. Blick former ADF&G, personal communication 1998; Cook 1998) and a multiple-trip estimate using a modified Jolly-Seber method to estimate the number of spawners returning across all trips (Seber 1982; Schwarz et al. 1993). A stratified two-sample mark-recapture study design was used for the stream-spawning population in Falls Lake. Darroch and pooled Petersen estimates were calculated using the program SPAS (Arnason et al. 1995).

Visual Survey Counts of Sockeye Spawners

Before each mark-recapture event, crew members recorded visual counts of sockeye spawners in defined areas around the entire lakeshore and in any inlet stream where spawners were present. A separate count was made within the “study area” or areas designated for the mark-recapture study. Any inlet stream with sockeye spawners present was defined as a separate area for counting, and it was designated as a “study area” if mark-recapture sampling was conducted in the stream. We attempted to have at least three observers for each survey. Each crewmember recorded his or her own counts separately. The counts gave a rough indication of the proportion of sockeye spawners within the defined study area at each sampling event. A single visual survey was conducted in Gut Bay Lake by four observers.

Beach Spawning Populations

The study design for beach-spawning populations consisted of two stages: 1) a two-sample Petersen estimate for each trip (Seber 1982) and 2) a multiple-trip estimate using a modified form of the Jolly-Seber method for multiple mark-recaptures in an open population (Seber 1982; Schwarz et al. 1993; Cook 1998). In the first stage, fish were marked on one day and examined for marks the next day. In the second stage, fish caught on both days of a given trip were given a unique mark for that trip. Then on subsequent trips recaptures of these marks were recorded. In the second stage we used the number of recaptures from each previous trip, together with the first-stage Petersen estimates of abundance from each trip, to generate an estimate fish that spawned within the study area over the entire season.

The crew used a 20 m long x 4 m deep beach seine, pulled by hand with the aid of a small skiff with outboard motor, to capture sockeye salmon on the spawning grounds. They first inspected all sockeye salmon for previous marks, then marked each fish with an opercular punch or pattern of punches indicating the trip and day number and released it with a minimum of stress. The crew leader recorded the total sample size, the number of new fish marked, and the number of recaptured fish with each type of mark. Sampling in these small populations continued until the number of same-day recaptures exceeded the number of new fish caught. Right opercular punches were the primary mark for each trip as follows: trip 1 – round, trip 2 – triangle, trip 3 – square, trip 4 – two round. A left opercular punch (any shape) was given each fish caught on the second day of each trip to indicate the fish had already been caught and should not be recounted on that trip.

Stream Spawning Population

At Falls Lake, stream-spawning sockeye salmon school around the gravel bar at the mouth of the inlet stream at the southwest corner of the lake, before going a short distance up the stream to spawn (Figure 3). All or nearly all spawning takes place in the stream channel between the mouth and a small partial-barrier falls about 0.8 km upstream. At Kutlaku Lake, stream-spawning sockeye salmon school around the gravel bar at the mouth of the stream entering about midway along the southeast side before going a short distance upstream to spawn (Figure 4). The delta area of this small stream has been substantially altered by the activity of beavers, and the channel depends also on water level, which can be very low during dry weather. In this study, the stream and its mouth were treated as a single area and the beach spawning study design was used.

We used a stratified, two-sample mark-recapture procedure to estimate escapement into the main Falls Lake inlet stream (Arnason et al. 1995). The crew sampled and marked sockeye salmon as they schooled up around the mouth of the inlet prior to going upstream to spawn (first samples). As soon as sockeye salmon were observed spawning within the inlet stream, the crew sampled fish in the stream (second samples) using a small barrier net or dipnets. All parts of the stream were sampled as evenly as possible.

The marking samples were stratified by time, using a distinct opercular punch shape identify strata: stratum 1 – round, stratum 2 – triangle, stratum 3 – square, stratum 4 – 2 round. The primary mark was put in the left operculum to distinguish fish from this stream area from those marked in the beach spawning area. In the recapture phase, fish caught upstream were examined for marks; carcasses were also examined for marks. Numbers of marked fish from each stratum and the number of unmarked fish were recorded. A secondary mark was given all live fish and carcasses in the second samples to prevent re-counting. Sample sizes were as large as practical but avoided multiple same-day recaptures. There were three marking and three recapture strata. The first trip coincided with the time that sockeye salmon were beginning to school off the stream mouth but before they entered the stream, beginning on 21 Aug. Only the marking phase was conducted on the first trip. On subsequent trips, spaced about two weeks apart, both the marking and recapture phases were conducted, until no more sockeye spawners were at the mouth of the stream. On the last trip, only the recapture phase was conducted; the last trip occurred when most of the spawners were dead or dying.

Data Analysis

The first-stage estimates for beach-spawning populations, or the "instantaneous" Petersen estimates within the study area, are formed using the method described in the Weir/Trap section above. This method is also used for pooled Petersen estimates of stream-spawning populations.

In the second-stage estimation process for beach-spawning populations, the first-stage Petersen estimates are used to estimate the total spawning population within the study area, N^*. Given s sampling occasions, we let $\hat{N}_i$ denote the first-stage Petersen population estimate from each sampling occasion i. The $\hat{N}_i$ values were used in place of the Jolly-Seber-derived parameter estimates of the number of animals alive in the system at each sampling occasion (J. Blick ADF&G, personal communication 1998; Cook 1998). We let n_i represent the number of unmarked fish and fish marked on previous trips, caught at sampling occasion i, and we let m_i represent the number of fish marked on previous trips, caught at sampling occasion i.

We also defined the following parameters (Schwarz et al. 1993; J. Blick ADF&G, personal communication, 1998; Cook 1998):

> M_i = number of marked fish alive at time i,
>
> ϕ_i = probability that a fish alive at time i is also alive at time i+1 (*i.e.* the survival rate)
>
> B_i = number of fish that enter the system after occasion i and are still alive at time i+1 (*i.e.* immigration).
>
> B_i^* = number of fish that enter the system after occasion i, but before occasion i+1,
>
> N^* = total number of animals that enter the system before the last sampling occasion.

M_i was estimated as $\hat{M}_i = m_i \hat{N}_i / n_i$, for $i = 1,\ldots,s$;

ϕ_i was estimated as $\hat{\phi}_i = \hat{M}_{i+1} / (\hat{M}_i - m_i + n_i)$, for $i = 1,\ldots,s-1$;

B_i was estimated as $\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}_i \hat{N}_i$, for $i = 1,\ldots,s-1$;

B_i^* was estimated as $\hat{B}_i^* = \hat{B}_i \log(\hat{\phi}) / (\hat{\phi} - 1)$, for $i = 2,\ldots..,s-1$, and

N^* was estimated as $\hat{N}^* = \sum_{i=0}^{s-1} \hat{B}_i^*$.

Recruitment and mortality were assumed to be uniform between times i and i+1. Because B_0^* and B_1^* are not uniquely estimable, $\hat{B}_0^* + \hat{B}_1^*$ was estimated by $\hat{N}_2 \log(\hat{\phi})/(\hat{\phi}-1)$.

A parametric bootstrap method (Buckland 1985 and 1984) was used to construct confidence intervals for the parameter estimates in both stages. Let each bootstrap step be indexed by j (j=1,...G; for our purposes G=1,000). The parametric bootstrap distribution for $\hat{N}_i$ was developed by drawing G bootstrap observations of a hypergeometrically distributed random variable (that is, r_i) using parameters based on the observed values of C_i, K_i, and $\hat{N}_i$ at each sampling event i. At each step $\hat{N}_i(j)$ is developed as previously described. Denote each bootstrap observation in the first estimation stage as the pair of $r_i(j)$ and $\hat{N}_i(j)$, for j = 1,...G. Before proceeding on to the simulation of the second stage (the Jolly-Seber portion), the variance of the number of recaptures across all bootstrap replicates was calculated and denoted sb_i, for each trip i (*i.e.*, $\mathrm{Var}_j(r_i(j))= sb_i$). Note this standard deviation is calculated from the bootstrap distribution of just recaptures from the previous-day's marking event. To simulate the Jolly-Seber portion, for each bootstrap step, a bootstrap observation, $m_i(j)$, was drawn from a normal distribution with the mean determined from the actual observed value of m_i, and the standard deviation given by sb_i. Because this standard deviation is based on the simulated variability in just the previous-day's marking, it may tend to understate the sampling variability of m_i, which is the number of recaptures from all previous marking events. Even so, this assumption should provide a sensible approximation. We condition on the sample size, assumed to be fixed and not a random variable, so that $n_i = n_i(j)$, for all j bootstrap observations. We then estimate $\hat{M}_i(j)$, $\hat{\phi}_i(j)$, and so on, as previously described, for all j = 1, ...G. The confidence interval for each parameter estimate is found from the quantiles of the bootstrap distribution (Rice 1995) for that estimate.

For the stream spawning population, we analyzed data from the three or four marking and recapture strata using Darroch, maximum-likelihood, Schaefer population, and "pooled Petersen" estimates, included in the Stratified Population Analysis System (SPAS) software (Arnason et al. 1995). Assumptions for full or partial pooling were tested, and we selected the most precise estimate that also did not violate the assumptions. A 95% confidence interval was constructed for the pooled Petersen estimate as given in the weir/trap section above. Since the inlet stream spawning areas of Falls Lake is short, the entire stream area was sampled and the estimate applies to the entire stream spawning population.

SUBSISTENCE HARVEST ESTIMATE

We used a one-stage stratified sampling design to estimate sockeye salmon harvest and fishing effort (Cochran 1977) at Falls Lake. Subsistence fishing was open at the Falls Lake terminal area from 1 June–6 July and from 14–20 July, 2003 and sport fishing was open the entire time the crew was at Falls Lake (3 May–5 Sept.); both fisheries were monitored daily throughout these time periods. The primary sampling units were boat–parties within days. This design was appropriate because participating boats could be accurately counted and most could be interviewed after they completed fishing. The design was stratified by angler type. Sport fishers (using hook and line) were one stratum, subsistence fishers using gillnets were a second stratum, and subsistence fishers using seines were a third stratum. The very low number of participants in the fishery allowed the crew to monitor the fishery seven days a week during all day-light hours. Experience showed that samplers could interview nearly all-participating groups during this time period; the exception was those boat parties that chose to leave the area without completing an interview. These instances were recorded as missed interviews; if the sampler was able to estimate a catch from observation or third person reporting, that was noted in the comments.

As a fishing boat entered the area, the sampler contacted the group by radio or by motoring out, gave a short explanation of the creel survey, determined the group's sport or subsistence gear use, and requested that the boat party contact the samplers as they prepared to leave the area so the interview could be completed. Data collected during each interview included angler effort (rod or net hours), gear type used, and harvest by species. If the technician was unable to interview a party because two or more boats were leaving at the same time, one boat was randomly selected using a coin toss. Samplers maintained a view of the fishing area during the entire sampling period. Boat parties that left the fishery without being interviewed were counted according to their previously identified sport or subsistence gear use, along with any other known information.

Equations for estimating harvest, catch, and effort in each harvest survey were those for a one-stage direct expansion (access point, completed-trip interview) survey (Cochran 1977; Conitz et al. 2002). We let h_j = harvest on boat j using gear g, m_g = number of boat parties interviewed using gear g, and M_g = number of boat-parties counted using gear g. The harvest (by species and gear group g) was estimated as,

$$\hat{H}_g = \frac{M_g}{m_g} \sum_{j=1}^{m_g} h_{gj} \tag{5}$$

Letting $\bar{h}_g$ denote the mean harvest per boat for the g^{th} gear group, the variance of the harvest by stratum was estimated as,

$$\mathrm{var}(\hat{H}_g) = (1 - \frac{m_g}{M_g}) M_g^2 \frac{\sum_{j=1}^{m_g} (h_{g,i} - \bar{h})^2}{m_g (m_g - 1)} \tag{6}$$

If all boat parties in a gear group were interviewed, the estimated harvest by species was simply the sum of the harvest on individual boats. Effort was estimated similarly, substituting E for H in the equations above. Subsistence total harvest for the season was the sum of harvests for the gillnet and seine groups.

LIMNOLOGY SAMPLING

Limnology sampling was conducted on four sampling dates in 2003, in Falls and Kutlaku Lakes only, beginning in late May and repeated at approximately six-week intervals through early October. Physical data were taken only at Station A (the main lake basin or deepest part of the lake). Zooplankton samples were collected from two stations on each sampling date (Conitz et al. 2002; Conitz and Cartwright 2002), and reported estimates are between-station averages.

Light, Temperature, and Dissolved Oxygen Profiles

Underwater light intensity was recorded from just below the surface to the depth where measured intensity was one % of the surface light reading, at 0.5 m intervals, using an electronic light sensor and meter (Protomatic). The vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface light) versus depth. The euphotic zone depth (EZD) was defined as the depth to which one % of the subsurface light [photosynthetically available radiation (400–700nm)] penetrates the lake surface (Schindler 1971), and was calculated from the equation, EZD = 4.6205/ K_d (Kirk 1994). The product of the euphotic zone depth and the surface area provides an estimate of the volume of the lake in which photosynthetic activity is possible.

Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments (YSI) Model 58 DO meter and probe, in relative (percent of saturation) and absolute (mg L^{-1}) values for DO and in ºC for temperature. Measurements were made at 1 m intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreased to less than 1ºC per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 50 m). The dissolved oxygen meter reading at 1 m was calibrated at the beginning of a sampling trip using the value from a 60 ml Winkler field titration (Koenings et al. 1987). The DO profile was measured only on the first sampling trip in May because in 2001 we found no major changes in DO profiles during the summer and early fall season.

Secondary Production

Zooplankton samples were collected at two stations using a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a maximum depth of 50 m, or 2 m from the bottom of the lake if shallower than 50 m, at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the ADF&G Commercial Fisheries Limnology Laboratory in Soldotna, Alaska. Identification to genus or species, enumeration, and density and biomass estimates were performed as in 2001 and 2002 (Conitz et al. 2002; Koenings et al. 1987). Zooplankton density (individuals per m^2 surface area) and biomass (weight per m^2 surface area) were estimated by species and by the sum of all species (referred to as total zooplankton density or biomass).

RESULTS

SOCKEYE SMOLT RUN TIMING, AGE AND SIZE ESTIMATES

We sampled smolt from 5 May through 18 June 2003, except 23–24 May when high water disrupted sampling. Sampling started at around 2000-hr each evening and continued for about 3 hrs, although the starting time varied by as much as ± 2 hr and the total sampling time ranged from about 15 min to 6 hr. Although most smolt were caught during a narrow period around sunset, we attempted to standardize the number caught per day by the total time fished (Figure 6). The high value of 492 smolts/hr on May 13 was obtained with only 15 min of fishing time, and may not be a reliable estimate. Excluding this extreme value, the mean number of smolts per hour was about 12, and the median number of smolts per hour on all dates was about 23. The highest total numbers and the highest average number per hour were at the beginning of the sampling period, so the peak of the run may have already occurred before the first day of sampling, 5 May.

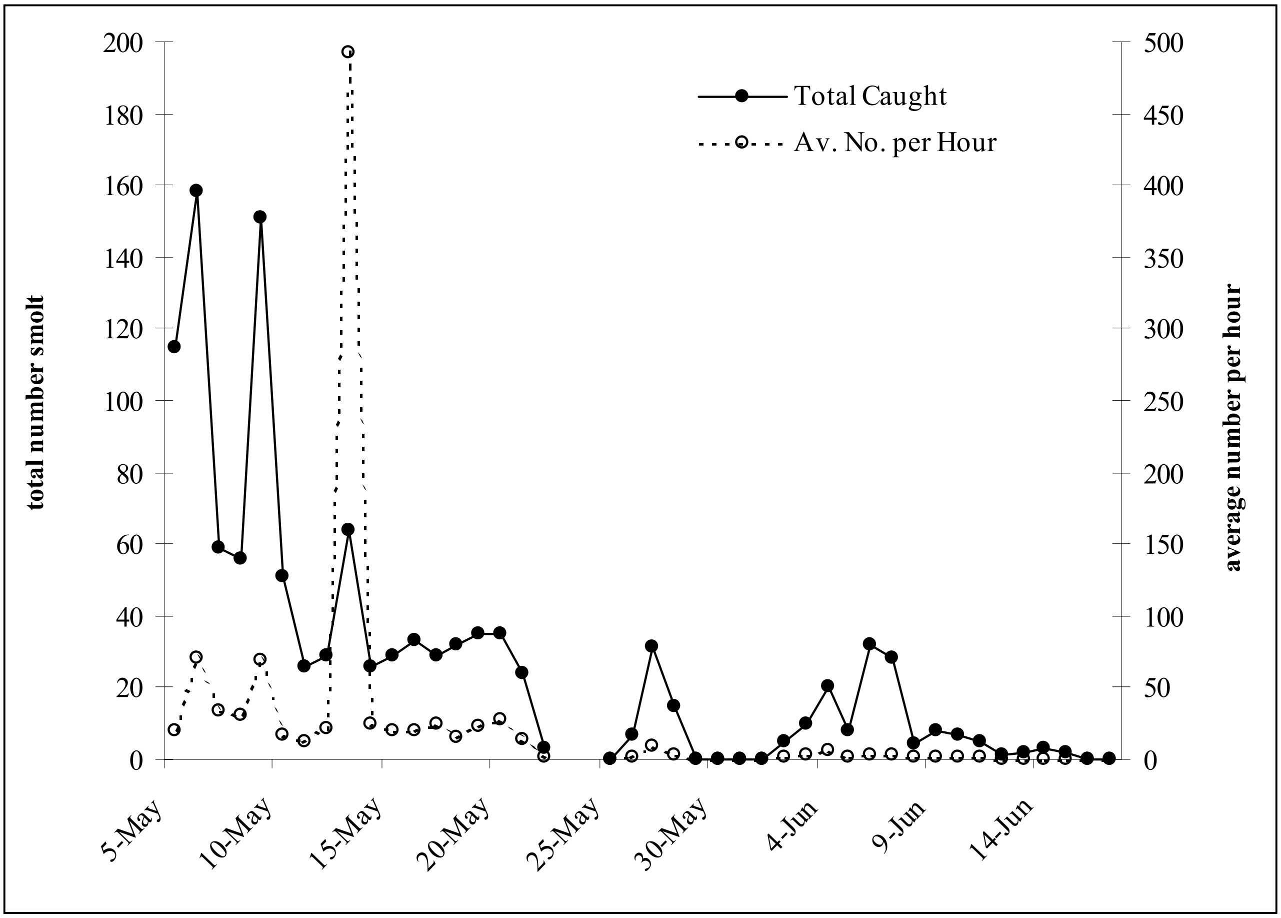

Figure 5. Numbers of sockeye smolts counted in fyke net samples at Falls Creek in 2003. Sampling started at an average time of 8:00 pm and lasted about 3 hrs on average each evening.

Out of 1,143 sockeye smolts caught and counted in the fyke, 544 sockeye smolts were sub-sampled for age, weight, and length (AWL). After sampling, the crew released them alive, except seven mortalities noted on 6 June. No other species were caught in the fyke. The 544 smolts that were AWL-sampled yielded 536 ageable scale samples. All of these were age 1. Average weight of the age-1 smolts was 2.95 g (std dev = 0.54) and their average length was 73 mm (std dev = 5.2). The average weight and length of the eight fish that were not aged were similar to those of the age-1 fish. We cannot conclude from these samples, however, that all sockeye smolts migrating out of Falls Lake in 2003 were age 1. Age-2 smolts generally migrate out early in the run, but it appears we did not start sampling at the beginning of the run.

ADULT ESCAPEMENT ESTIMATES

Weir/Trap

Between 11 July and 4 September, 2,222 sockeye salmon were counted through the trap at the top of the Falls Lake fish ladder (Table 4). All of these fish were marked with fin clips. The trap was in place beginning 10 June, but no sockeye salmon passed through it before 11 July. Daily escapement through the fish ladder was above zero through the entire escapement period, except for one day (7 Aug.), but was down to 10 or fewer fish by 24 Aug. (except 31 Aug., with 13 sockeye salmon; Appendix C). Peak escapement through the fish ladder of 272 sockeye salmon on 21 July coincided with a small peak in water level. Other species counted through the trap were 98 coho salmon, 113 pink salmon, 5 chum salmon, and 33 Dolly Varden char. These counts are likely incomplete, especially for the later-running coho salmon, and the smaller fish that could have escaped through the pickets of the trap without being counted.

Marking was stratified into three, non-overlapping time periods, with a different secondary fin clip for each period (early-left axillary, middle–left ventral, late–dorsal; Table 5); the primary mark was an adipose clip given to every fish. Four recapture events were conducted on the spawning grounds between 21 Aug. and 29 Sept., approximately two weeks apart; each event constituted one recapture stratum.

A first analysis using the SPAS program failed to converge upon a valid maximum-likelihood Darroch estimate. The least-squares Darroch estimate was 6,100, but the estimate contained two inadmissible intermediate estimates, a negative stratum size and a negative capture probability. The goodness-of-fit test for "complete mixing" was not significant (X^2 =2.08 on 2 degrees of freedom and p-value=0.35), while the test for "equal proportions" was (X^2 =40.42 on 2 degrees of freedom and p-value<0.01). Because at least one test was not significant, a partial pooling of the data was attempted. The first two and last two recapture strata were pooled (Table 6). Partial pooling resulted in a valid maximum likelihood Darroch estimate of 5,600 in 3 iterations, and standard error of 335 (CV=6%). Results of the test for "complete mixing" were unchanged from those with the unpooled data. Results of the "equal proportions" test were also similar (X^2 = 37.34 on one degree of freedom and p-value<0.01). The pooled Petersen estimate was 5,700 with standard error of 208 (CV 4%; 95% CI 5,100-6,500). We used the pooled Petersen estimate because at least one of the goodness-of-fit tests passed.

Table 5.–Number of sockeye salmon marked at the Falls Lake fish ladder, and sample sizes and recapture numbers on the spawning grounds in Falls Lake, 2003. All sockeye salmon passed through the trap at the top of the fish ladder were marked. Recapture sampling was conducted in all spawning areas of the lake and its inlet streams throughout the spawning period.

Phase	Stratum	Dates	Total Marked
Marking	1 (early)	11–22 Jul	879
	2 (middle)	23 Jul–6 Aug	608
	3 (late)	7 Aug–4 Sep	735
		Total marked:	**2,222**

				Number recaptures by stratum		
			Sample size	**1**	**2**	**3**
Recapture	1	21 Aug	421	72	41	18
	2	1 Sep	273	35	26	35
	3	20 Sep	176	23	29	37
	4	29 Sep	107	19	18	26
		Total sampled:	**977**			
			Total recaps (all strata):	**380**		

Table 6.–Partial pooling of recapture strata in Falls Lake 2003 weir mark-recapture dataset.

				Number recaptures by stratum		
Phase	**Stratum**	**Date**	**Sample size**	**1**	**2**	**3**
Recapture	1–2	21 Aug/1 Sep	694	107	67	53
	3–4	20 Sep/29 Sep	283	42	47	63
		Total sampled:	977			
		Total recaps (all strata):		380		

Mark-Recapture and Visual Survey Escapement Estimates

Falls Lake

Biologists and crew accomplished all visual survey counts and mark-recapture sampling of sockeye spawners in the beach and inlet stream spawning areas in Falls Lake during four trips between 17 August and 30 September 2003 (Tables 7–9). We found moderate numbers of sockeye salmon spawning and available for sampling in the beach study area, and larger numbers of sockeye spawners in the SW (main) inlet stream. We estimated a total of about 1,300 (95% CI 1,250–1,500) sockeye salmon in the beach study area, and we met our objective for precision with an estimated coefficient of variation (CV) of 4.9%.

We analyzed mark-recapture data collected in the SW inlet stream using the SPAS program. The chi-square test for "complete mixing" yielded the statistic X^2 = 2.02 with 2 degrees of freedom and p-value = 0.36. The chi-square test for "equal proportions" test yielded the statistic X^2 = 13.76 with 2 degrees of freedom and p-value < 0.01. A maximum-likelihood Darroch estimate was produced with one iteration and no out-of-bounds intermediate estimates; this estimate was about 2,350 with standard error of 180 (CV = 7.6%). By comparison, the pooled Petersen estimate was about 2,300 (95% CI 2,100–2,700; CV = 6.6%). Because one of the two goodness-of-fit tests passed, we considered it valid to use pooled Petersen estimate.

When we summed the estimate of sockeye salmon spawning in the SW inlet stream with the estimate for beach spawners within the study area, we obtained a minimum escapement estimate for the Falls Lake study areas of about 3,700 (range 3,300–4,200). About 70% of the beach spawners overall were observed within the beach study area and available for sampling (Table 7). All of the stream spawners were considered to be available for sampling.

Table 7.–Visual counts of sockeye salmon spawners in Falls Lake in 2003, listed individually by observer (2 – 4 observers). Counts were made in the SW inlet stream on foot; shoreline areas were surveyed by boat. The study area was a designated area within the total lake shoreline area.

	Sockeye Counts		
Date	**SW Inlet Stream**	**Beach Study Area**	**Entire Lake Shore**
21 Aug	381, 359, 320, 317	82, 85, 85, 99	89, 106, 96, 120
2 Sep	741, 702, 750, 731	242, 267, 281, 290	321, 360, 368, 388
19 Sep	1077, 1028, 1038, 1069	174, 129, 134, 169	223, 186, 201, 217
30 Sep	287, 282	108, 81	127, 99

Table 8.–Sample sizes and numbers of recaptured fish in the main beach spawning area at Falls Lake in 2003, designated as the study area.

Event Dates	First Stage				
	No. Marked (day 1)	No. Sampled (day 2)	No. Recaps from day 1		
17–18 Aug	136	241	29		
1–2 Sep	186	219	49		
20–21 Sep	134	164	75		
29–30 Sep	108	90	63		
	Second Stage				
	No. Marked	**Recaps from event:**	**1**	**2**	**3**
17–18 Aug	348		-	-	-
1–2 Sep	356		63	-	-
20–21 Sep	223		27	72	-
29–30 Sep	135		3	21	69

Note: In the first stage sampling, fish were marked on one day and examined for marks the following day, assuming the population to be closed over this short time period. In the second stage sampling, fish caught on both days of an event were given a unique mark for that event, and were also examined for marks given on previous events. The second stage allowed for an open population estimate.

Table 9.–Sample sizes in mark and recapture strata and numbers of marked fish caught in recapture strata in southwest inlet stream to Falls Lake, 2003. Marking was conducted at the mouth of the stream; recapture sampling was conducted in the stream.

Phase	Stratum	Dates	Number marked			
Marking	1	21 Aug	265			
	2	1 Sep	245			
	3	20 Sep	51			
		Total marked:	561			
				Recaptured fish by stratum:		
			Sample size	**1**	**2**	**3**
Recapture	1	31 Aug	234	38	-	-
	2	20 Sep	203	19	39	-
	3	29 Sep	110	3	16	16
		Total sampled:	547			
			Total recaps (all strata):	131		

Kutlaku Lake

Biologists and crew conducted mark-recapture sampling and visual survey counts of sockeye spawners in Kutlaku Lake between 16 August and 8 October 2003 (Tables 10–12). Early in the season, most sockeye spawners were concentrated in and around the main inlet stream on the SE side of the lake; we started mark-recapture studies there on 16 August using the modified Jolly-Seber ("beach spawning") design. We used the modified Jolly-Seber design because sampling encompassed the entire spawning area, including the mouth of the stream and all reaches with spawners present. The closure assumption for the first-stage sampling required that few fish entered or left this study area over a given two-day period; this assumption was probably violated later in the spawning period when many more beach-spawners were present all around the lake.

Poor results in data analysis suggest the choice of the "beach spawning" sampling design may have been inappropriate. We recovered very few marks on the first and last trips, resulting in large variance estimates (CVs of 31% and 46%), for the respective first-stage estimates. We also observed large differences in recapture rates between the mouth of the stream and the stream channel, and weather forced a long delay between trips 2 and 3, when maximum numbers of spawners were present in the study area. Apparently, some of the assumptions, including closure and equal catchability, may have been violated on at least some of the sampling occasions. The escapement estimate for this study area was 3,600 (95% CI 3,000–5,100), with an estimated CV of 15.2%, which just fails to meet our objective for precision. Given the problems with this data set (e.g. low recapture numbers) and possible violations of mark-recapture assumptions, this estimate may not be reliable.

We obtained a better mark-recapture estimate in the beach spawning area designated as study area 2. The modified Jolly-Seber method yielded an estimate of about 1,700 sockeye spawners (95% CI 1,600–1,800) in this study area, with CV = 4.2%, easily meeting our objective for precision. The number of sockeye spawners increased in all beach spawning areas around the lake late in the season; study area 2 represented about 20% overall of the beach-spawning sockeye salmon in Kutlaku Lake.

Table 10.–Visual counts of sockeye spawners in Kutlaku Lake in 2003, listed individually by date and observer (2 – 4 observers). Counts were made in the main inlet stream on foot; counts along all shoreline areas of the lake were made by boat. The study area was a designated area within the total lake shoreline area.

	Average Sockeye Count		
Date	**Inlet stream (including mouth)**	**Beach study area**	**All beach spawning areas**
16 Aug	39, 42, 24, 26	21, 30, 30, 35	45, 54, 50, 60
30 Aug	456, 301, 309	25, 8, 8	71, 39, 40
17 Sep	267, 288, 232, 241	124, 101, 131, 128	469, 425, 497, 477
26 Sep	65, 47, 63	293, 216, 301	1105, 1034, 1272
8 Oct	6,6	243, 239	1469, 1474

Table 11.–Sample sizes and numbers of recaptured fish in the main inlet stream spawning area at Kutlaku Lake in 2003, designated as study area 1.

	First Stage				
Event Dates	**No. Marked (day 1)**	**No. Sampled (day 2)**	**No. Recaps from day 1**		
17–18 Aug	37	135	6		
29–30 Aug	205	187	34		
17–18 Sep	248	162	55		
26–27 Sep	31	56	2		
	Second Stage				
	No. Marked	**Recaps from event:**	**1**	**2**	**3**
17–18 Aug	166		-	-	-
29–30 Aug	358		65	-	-
17–18 Sep	355		3	7	-
26–27 Sep	85		1	3	20

Note: In the first stage sampling, fish were marked on one day and examined for marks the following day, assuming the population to be closed over this short time period. In the second stage sampling, fish caught on both days of an event were given a unique mark for that event, and were also examined for marks given on previous events. The second stage allowed for an open population estimate.

Table 12.–Sample sizes and numbers of recaptured fish in the beach spawning study area at Kutlaku Lake in 2003, designated as study area 2.

Event Dates	First Stage			
	No. Marked (day 1)	No. Sampled (day 2)	No. Recaps from day 1	
17–18 Sep	58	113	16	
26–27 Sep	350	390	120	
7–8 Oct	263	262	138	
	Second Stage			
	No. Marked	**Recaps from event:**	**1**	**2**
17–18 Sep	155		-	-
26–27 Sep	620		68	-
7–8 Oct	387		4	125

Note: In the first stage sampling, fish were marked on one day and examined for marks the following day, assuming the population to be closed over this short time period. In the second stage sampling, fish caught on both days of an event were given a unique mark for that event, and were also examined for marks given on previous events. The second stage allowed for an open population estimate.

Gut Bay Lake

We conducted only one visual survey in Gut Bay Lake in 2003, on 19 August. Four observers counted 138, 144, 149, and 150, respectively, around the lake perimeter, for an average total count of 145 sockeye salmon. Attempts to estimate sockeye escapement on the spawning grounds have been discontinued at Gut Bay Lake.

Adult Sockeye Population Age and Size Distribution

Falls Lake

At Falls Lake, 839 sockeye salmon were sampled for sex, length and scales, and ages were determined in 705 of the scale samples. Of those fish that were aged, 297 (42.1%) were males and 408 (57.9%) were females (Table 13). Five-year-old fish dominated the 2003 escapement, about evenly split between age-1.3 fish (35%) and age-2.2 fish (37%). Four-year-old, age-1.2 fish comprised the third largest category (22.1%) in the 2003 escapement. The overall average mid-eye to fork length was 518 mm (Table 14). Fish with two ocean years dominated the escapement and were smaller, averaging about 495 mm in length, than fish with three ocean years, which averaged about 550 mm in length.

Table 13.–Age composition of adult sockeye salmon in the Falls Lake escapement by sex, 2003.

Brood Year	2000	1999	1998	1999	1998	1997	
Age	**1.1**	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**	**All aged**
Male							
Number	5	59	133	1	81	18	297
Percent	0.7	8.4	18.9	0.1	11.5	2.6	42.1
SE (%)	0.3	1.0	1.5		1.2	0.6	1.9
Female							
Number		97	113		179	19	408
Percent		13.8	16.0		25.4	2.7	57.9
SE (%)		1.3	1.4		1.6	0.6	1.9
All Fish							
Number	5	156	246	1	260	37	705
Percent	0.7	22.1	34.9	0.1	36.9	5.2	
SE (%)	0.3	1.6	1.8		1.8	0.8	

Table 14.–Mean fork length (mm) of adult sockeye salmon in the Falls Lake escapement by sex and age class, 2003.

Brood Year	2000	1999	1998	1999	1998	1997		
Age	1.1	1.2	1.3	2.1	2.2	2.3	not aged	all fish
Male								
Sample Size	5	59	133	1	81	18	58	355
Av. Length	350	498	560	354	495	549	527	525
SE (av. Length)	8.3	2.9	1.9		2.5	5.8	5.9	2.4
Female								
Sample Size		97	113		179	19	75	483
Av. Length		491	554		497	548	510	513
SE (av. Length)		1.9	1.9		1.7	4.8	3.7	1.6
All Fish								
Sample Size	5	156	246	1	260	37	134	839
Av. Length	350	493	557	354	496	548	517	518
SE (av. Length)	8.3	1.6	1.3		1.4	3.7	3.4	1.4

Kutlaku Lake

At Kutlaku Lake, 632 sockeye salmon were sampled for sex, length, and scales, and ages were determined in 528 of the scale samples. Among those fish that were aged 304 (57.6%) were male and 224 (42.4%) were female (Table 15). Of the males that were aged, 71 were jacks (age-1.1 and age-2.1), representing an estimated 13.5% of the escapement. The dominant class for both sexes was age 1.3, representing an estimated 73.9% of the escapement; 10.8% were age 1.2. The overall average length of sockeye salmon sampled in Kutlaku Lake was 500 mm, with males smaller on average (483 mm) than females (523 mm) due to the high numbers of jacks (Table 16). The average mid-eye to fork length of age-1.3 fish was 533 mm.

Table 15.–Age composition of adult sockeye salmon in the Kutlaku Lake escapement by sex and brood year, 2003.

Brood Year	2000	1999	1998	1999	1998	1997	
Age	1.1	1.2	1.3	2.1	2.2	2.3	All aged
Male							
Numbers	70	37	191	1	4	1	304
Percent	13.3	7.0	36.2	0.2	0.8	0.2	57.6
SE (%)	1.5	1.1	2.1		0.4		2.2
Female							
Numbers		20	199		3	2	224
Percent		3.8	37.7		0.6	0.4	42.4
SE (%)		0.8	2.1		0.3	0.3	2.2
All Fish							
Numbers	70	57	390	1	7	3	528
Percent	13.3	10.8	73.9	0.2	1.3	0.6	100.0
SE (%)	1.5	1.4	1.9		0.5	0.3	

Table 16.–Mean fork length (mm) of adult sockeye salmon in the Kutlaku Lake escapement by sex, brood year, and age, 2003.

Brood Year	2000	1999	1998	1999	1998	1997		
	1.1	1.2	1.3	2.1	2.2	2.3	not aged	All Fish
Male								
Av. Length (mm)	336	466	539	331	496	521	490	483
SE (length)	2.3	3.5	1.6		2.8		9.3	4.4
Sample Size	70	37	191	1	4	1	66	370
Female								
Av. Length (mm)		480	528		459	512	524	523
SE (length)		4.4	1.3		10.9	7.0	4.1	1.5
Sample Size		20	199		3	2	38	262
All Fish								
Av. Length (mm)	336	471	533	331	480	515	503	500
SE (length)	2.3	2.9	1.1		8.7	5.0	6.3	2.8
Sample Size	70	57	390	1	7	3	104	632

Subsistence Harvest Estimate

Subsistence fishing was open at the Falls Lake terminal area from 1 June – 6 July and from 14–20 July in 2003 and sport fishing was open through September. Subsistence fishing began in the area on 5 July and occurred on every day thereafter when the fishery was open (Figure 6). Sport fishing was intermittent from 30 June – 2 August. Subsistence effort for the season totaled 28 nets (17 beach seines and 11 gill nets) fishing 172 total hours; sport fishing effort totaled 24 rods and about 25 hours. The crew was able to count all subsistence and sport boats participating in the fishery between May and early September, and there is little evidence that any fishing occurs outside of that time period. The crew interviewed all but one of these boat parties; the missed interview was a subsistence boat fishing a gillnet on 18 July, that left without reporting in to the crew.

The total estimated sockeye harvest by all gear types was about 2,730; only 90 of these fish (about 3% of the total) were taken by sport gear (Table 17). Total harvest of other species was small: about 105 pink salmon, 115 chum salmon, three coho salmon, and one Chinook salmon, all except two pink salmon taken by subsistence gear. Over 80% of the harvest occurred during the second subsistence opening, 14–20 July. Subsistence gillnetters expended the greatest amount of effort, 93 total gear-hours, during the 2003, and harvested an average of eight sockeye salmon per gear-hour fished (Table 18). Subsistence fishers using beach seines fished fewer hours, but had a much higher catch-per-effort, at 34 sockeye salmon per gear-hour fished. Average time fished per unit of gear (net) was similar for both subsistence groups, about 5 hrs. Sport fishers put in about one hour of fishing time per person (rod), and averaged about four sockeye salmon per hour fished.

LIMNOLOGY SAMPLING

Light, Temperature, and Dissolved Oxygen Profiles

Seasonal mean euphotic zone depths (EZD) in 2003 were about 10 m in Falls Lake, and about 8 m in Kutlaku Lake (Table 18). Euphotic zone depth was greatest (about 12 m) in Falls Lake in early summer, but increased through the summer in Kutlaku Lake to an August maximum of about 9 m. The minimum depths for the season at both lakes occurred in late September, coinciding with heavy rainfall and maximum sediment input.

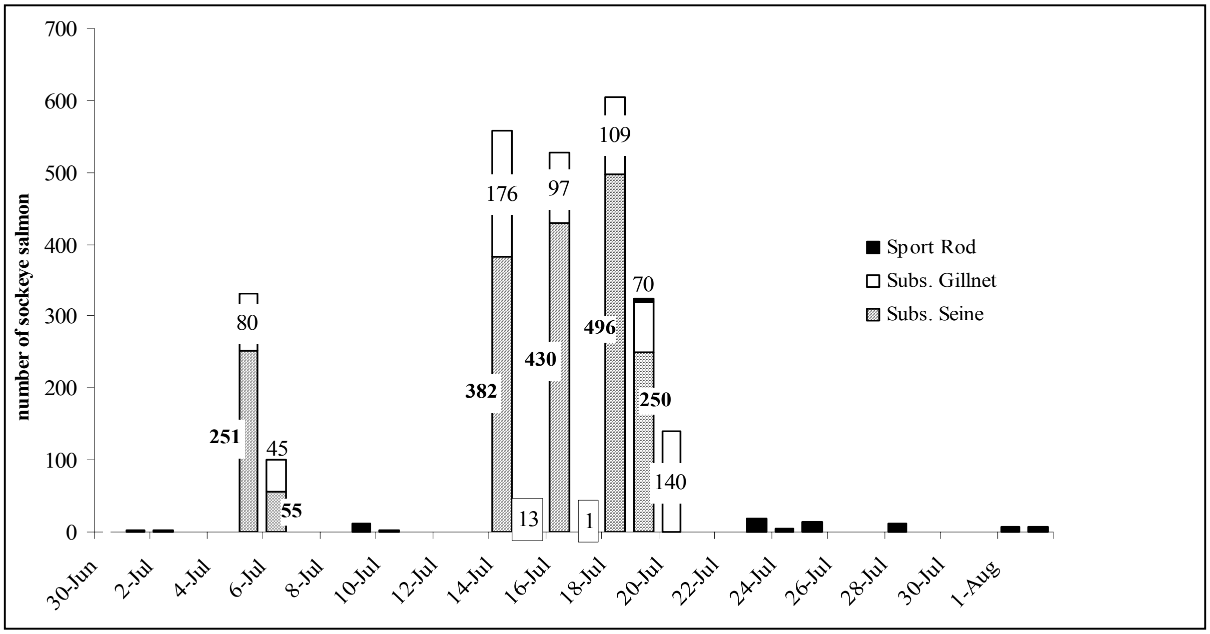

Figure 6.–Daily harvests of sockeye salmon reported in on-site interviews at the Falls Lake terminal area during the 2003 season.

Note: Daily totals are indicated in bold font for subsistence seine gear and regular font for subsistence gillnets. One gillnet interview was missed on 18 Jul. Daily sport totals are not shown but were always less than 20 sockeye salmon.

Table 17.–Number of salmon harvested in the Falls Lake sport and subsistence fisheries during 2003. Gillnet harvest was estimated (± standard error) due to one missed interview with a subsistence gillnet boat. Subsistence seine and sport harvests are based on 100% interviews and are considered total counts, without variance.

Gear Type	Boats Counted	Boats Interviewed	Sockeye	Chum	Pink	Coho	Chinook
Seine	11	11	1,864	57	2	0	0
Gillnet	17	16	777 ± 43	55 ± 5	107 ± 18	3 ± 1	1 ± 0
Sport	24	24	90	0	2	0	0
Totals	52	51	2,731 ± 43	112 ± 5	111 ± 18	3 ± 1	1 ± 0

Table 18.–Summary of fishing effort and catch-per-unit effort by gear type in the Falls Lake terminal area, 2003.

		Subsistence			
	Sport	Gillnet	Beach Seine	All Subsistence	All Gear Types
Total # nets or rods	24	17	11	28	52
Total gear hours	25	93	55	148	172
Average hours fished per unit of gear	1.0	5.5	5.0	5.3	3.3
Average sockeye catch per hour	4	8	34	18	16

Table 19.–Euphotic zone depths in Falls and Kutlaku Lakes, 2003.

Lake	Date	Depth (m)
Falls	27-May	11.59
	8-Jul	11.87
	20-Aug	8.55
	29-Sep	6.48
	seasonal mean	9.62
Kutlaku	5-Jun	7.93
	1-Jul	8.50
	17-Aug	9.16
	27-Sep	6.09
	seasonal mean	7.92

Falls Lake showed weak thermal stratification by 20 August, with a thermocline from about 8 to 9 m (Figure 8). The maximum epilimnetic temperature measured was 16.8°C in early July. Thermal stratification was very weak in Kutlaku Lake, with a thermocline beginning to form at about 8 m in late August (Figure 9). The maximum epilimnetic temperature in Kutlaku Lake, 16.3°C, also occurred in late August. Dissolved oxygen (DO) levels remained above 90% saturation at all depths in Falls Lake in the early part of the season, but dropped to about 85 to 90% in August (Table 20). The DO profile was measured only once in early July in Kutlaku Lake; at that time, DO levels declined with depth to 70% at the station depth (17 m).

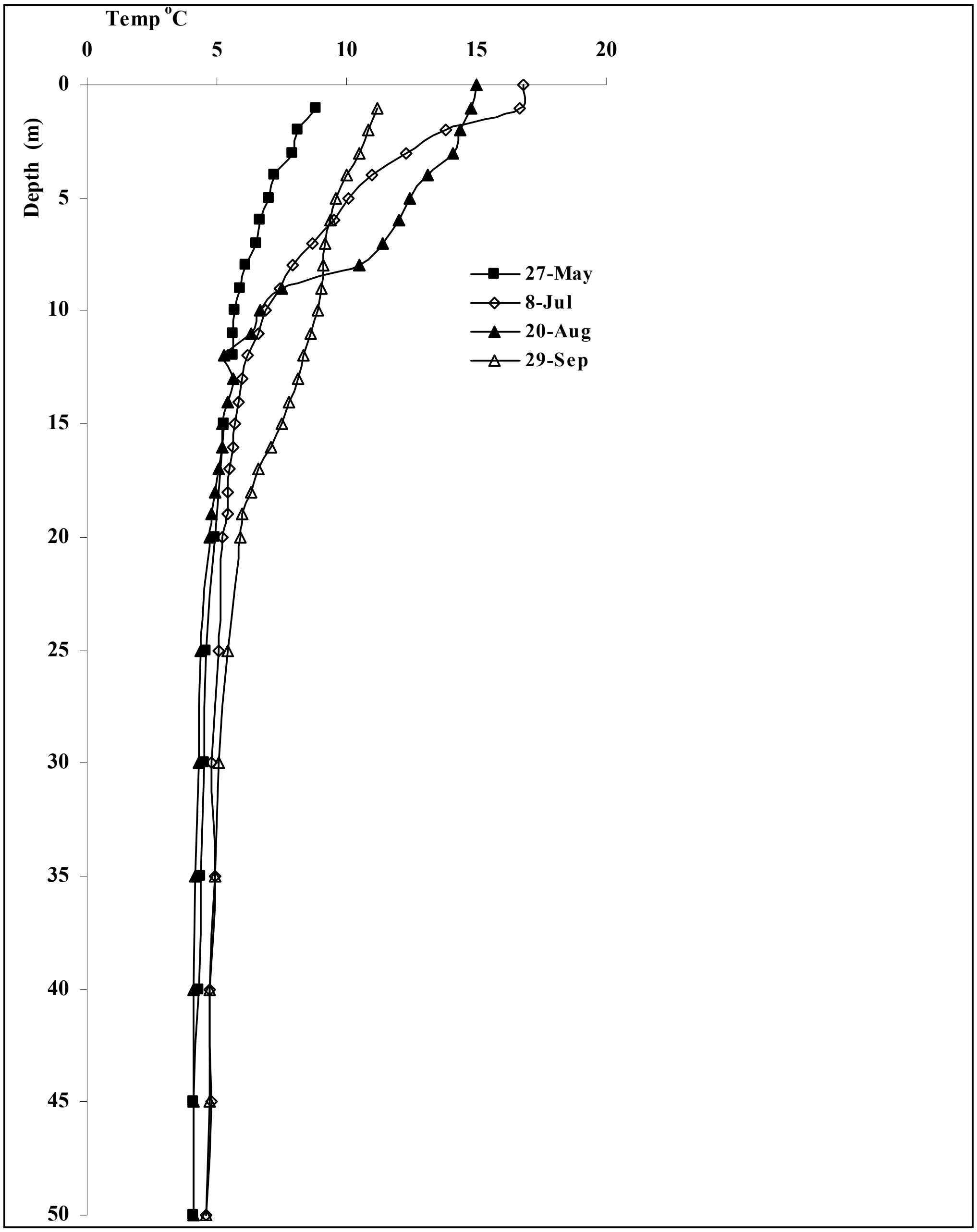

Figure 7.–Water column temperature profiles from Falls Lake, Station A, in 2003.

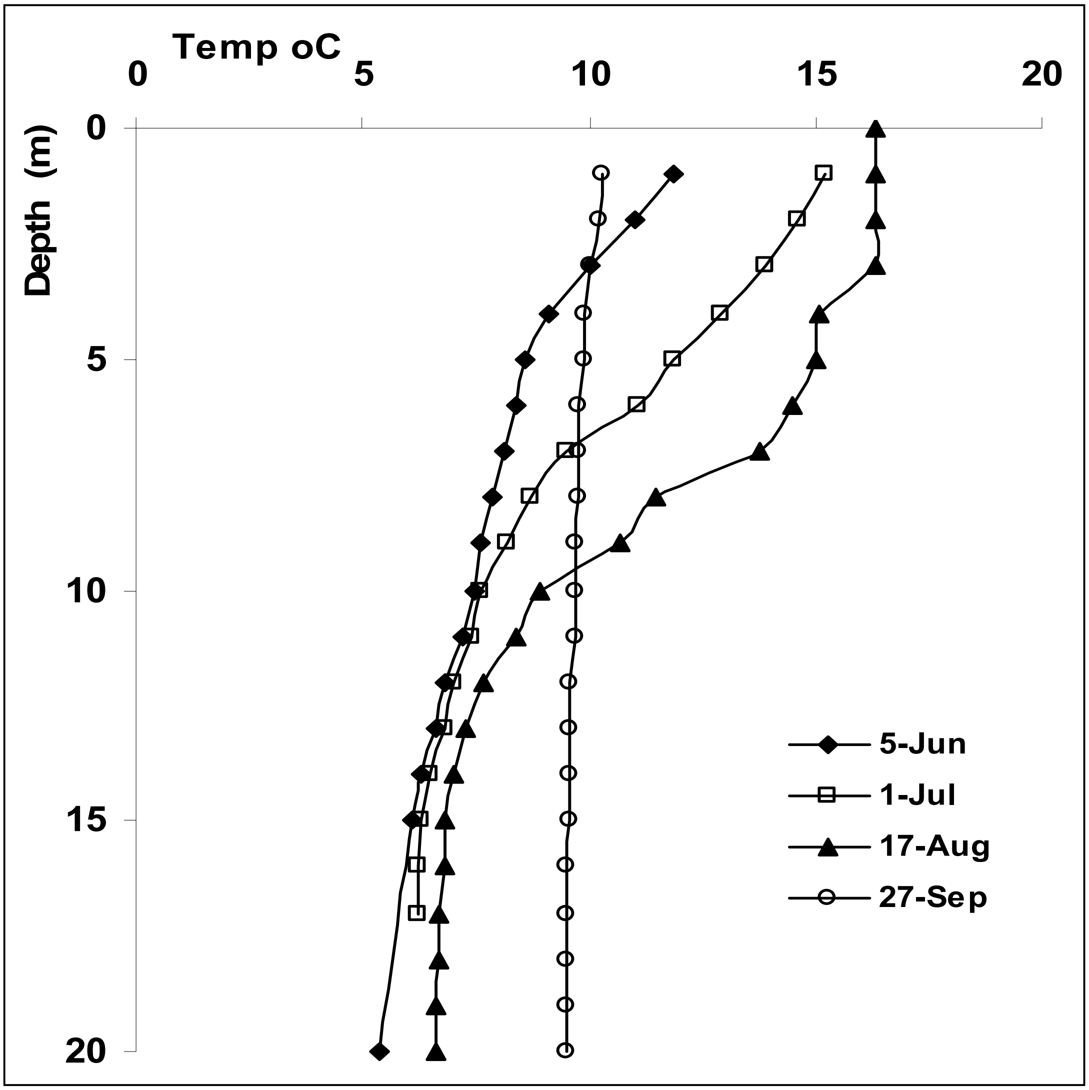

Figure 8.–Water column temperature profiles in Kutlaku Lake, Station A, in 2003.

Table 20.–Water column dissolved oxygen profiles in Falls Lake (May, July, Aug) and Kutlaku Lake (July only), 2003.

		Dissolved Oxygen by Date (% Saturation)				
Depth (m)	**Falls**	**27 May**	**8 Jul**	**20 Aug**	**Kutlaku**	**1 July**
0			98.5	90.0		
1.0		107.2	95.6	89.0		101
2.0		109.6	102.0	87.0		100
3.0		109.6	99.0	91.0		100
4.0		108.4	99.8	91.8		99
5.0		108.1	100.5	92.0		98
6.0		107.9	101.8	93.2		97
7.0		107.3	100.9	89.4		93
8.0		107.0	98.4	91.4		93
9.0		106.1	96.7	89.0		89
10.0		106.0	95.0	89.4		88
11.0		105.9	94.8	87.0		84
12.0		105.9	93.6	87.5		84
13.0			93.8	85.9		78
14.0			93.3	86.5		77
		Dissolved Oxygen by Date (% Saturation)				
Depth (m)	**Falls**	**Depth (m)**	**Falls**	**Depth (m)**	**Falls**	**Depth (m)**
15.0		104.7	93.5	85.7		71
16.0			93.0	85.9		71
17.0			93.1	86.2		70
18.0			92.8	85.7		
19.0			93.0	85.0		
20.0		103.7	92.9	86.0		
25.0		102.7	93.4	86.0		
30.0		102.6	92.0	86.4		
35.0		101.8	92.3	86.5		
40.0		101.8	91.6	86.2		
45.0		101.1	92.2	85.1		
50.0		100.5	90.0	84.5		

Secondary Production

Major taxa of macro-zooplankton identified in water samples from Falls and Kutlaku Lakes were cladocerans *Bosmina* sp. and *Daphnia longiremus*, and the copepod *Cyclops* sp. Additionally, the copepod *Diaptomus franciscanus* was present in Falls Lake samples, and cladocerans *Holopedium* sp. and Sidadae were present in Kutlaku Lake samples.

Falls Lake

Mean seasonal biomass of all zooplankton was less than 50 $mg \cdot m^{-2}$ in Falls Lake in 2003 (Table 21). About 70% of the biomass, on average, was copepods, and *Bosmina* comprised most of the remaining biomass. Copepods were relatively large, with average body lengths of 0.9 – 1.6 mm in the late season, but cladocerans had smaller average lengths of 0.4–0.8 mm. Copepods were also dominant numerically, making up about 70% of the seasonal mean density of all zooplankton (Table 22). *Daphnia*, the preferred prey of juvenile sockeye salmon, comprised about 3 to 6% of both biomass and total numbers in Falls Lake, and their numbers increased dramatically in the fall.

Table 21.–Size and biomass of macrozooplankton in Falls Lake, 2003, averaged between Stations A and B. Mean lengths are weighted by density (numbers · m^{-2}) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Av. Length (mm)						
	20-May	**8-Jul**	**20-Aug**	**29-Sep**	**Weighted Mean Length (mm)**	**Seasonal Mean Biomass (mg·m^{-2})**	**% of Total Biomass**
Bosmina	0.50	0.40	0.43	0.46	0.45	8.38	28.7%
Ovig. *Bosmina*			0.64	0.62	0.47	0.14	0.4%
Daphnia longiremis	0.74	0.73	0.66	0.66	0.66	1.05	3.7%
Ovig. *D. longiremis*	0.00	0.89	0.86	0.89	0.86	0.27	1.0%
Cyclops	0.47	0.60	0.65	0.75	0.61	8.56	29.5%
Ovig. *Cyclops*			1.06	1.14	1.07	0.41	1.2%
Diaptomus	0.69	1.00	1.35	1.50	1.04	9.87	33.0%
Ovig. *Diaptomus*			1.55	1.62	1.61	1.97	6.0%
					Total Seasonal Mean Biomass	**29.46**	

Table 22.–Density (thousands per m^2) of macrozooplankton by taxon in Falls Lake, 2003, averaged between Stations A and B.

	Density (thousands · 1000m^{-2})					
	20 May	**8 Jul**	**20 Aug**	**29 Sep**	**Seasonal Mean**	**% of Total Numbers**
Bosmina	1.3	4.2	4.4	7.6	4.4	26.7%
Ovig. *Bosmina*	0	0	0.2	0.1	0.6	0.3%
Daphnia longiremis	0	0.2	0.7	1.2	0.6	3.4%
Ovig. *D. longiremis*	0	0.1	0.1	0.1	0.1	0.5%
Cyclops	1.6	18.8	5.1	1.9	6.9	42.0%
Ovig. *Cyclops*	0	0	0.2	0	0	0.3%
Diaptomus	1.7	3.7	2.0	0.6	2.0	12.1%
Ovig. *Diaptomus*	0	0	0	0.2	0.1	0.4%
Copepod nauplii	5.7	2.1	1.4	0.3	2.4	14.4%
			Seasonal Mean Density, All Taxa		**16.0**	

Kutlaku Lake

Seasonal mean biomass of all zooplankton was about 600 mg·m^{-2} in 2003, but 75–80% of this biomass was the large, gelatinous *Holopedium* (Table 23). Excluding this taxon, the seasonal mean biomass in Kutlaku Lake was about 120–150 mg·m^{-2}. *Daphnia* and *Bosmina* were the next-largest components of biomass in the Kutlaku Lake samples, but average body lengths in both taxa were small, about 0.3 mm for *Bosmina* and about 0.5–0.7 for *Daphnia*. Seasonal mean zooplankton density was about 225,000 plankters·m^{-2} (Table 24). Next to *Holopedium*, *Daphnia* were the most numerous taxon in Kutlaku Lake, and their numbers increased by over 30-fold between early June and late summer, while *Holopedium* numbers fell to zero by the end of season. *Bosmina* were present in slightly smaller numbers than *Daphnia*, but fell to very low numbers at the end of the season.

Table 23.–Size and biomass of macrozooplankton in Kutlaku Lake, 2003, averaged between Stations A and B. Mean lengths are weighted by density (numbers · m^{-2}) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Av. Length (mm)						
	5 Jun	1 Jul	17 Aug	27 Sep	Weighted Mean Length (mm)	Seasonal Mean Biomass ($mg{\cdot}m^{-2}$)	% of Total Biomass
Bosmina	0.34	0.33	0.31	0.30	0.32	53.03	0.09
Ovig. *Bosmina*		0.39	0.39		0.39	0.76	0.00
Daphnia longiremis	0.51	0.58	0.50	0.48	0.51	67.59	0.11
Ovig. *D. longiremis*	0.73	0.73	0.79	0.66	0.77	12.34	0.02
Holopedium	0.61	0.80	0.76		0.71	401.11	0.65
Ovig Holopedium	0.86	0.87	0.86		0.86	81.46	0.13
Sidadae			2.60				
Cyclops	0.54	0.49	0.79	0.55	0.56	2.83	0.00
				Total Seasonal Mean Biomass		**619.13**	

Table 24.–Density (thousands per m^2) of macrozooplankton by taxon in Kutlaku Lake, 2003, averaged between Stations A and B.

	Density (thousands · m^{-2})					
	5-Jun	1-Jul	17-Aug	27-Sep	Seasonal Mean	Percent of Total
Bosmina	41.4	58.1	134	1.0	59.7	26.1%
Ovig. *Bosmina*	0	0.3	2.0	0	0.6	0.2%
Daphnia longiremis	2.1	16.6	127	106	63.0	27.8%
Ovig. *D. longiremis*	1.3	3.1	13.6	1.0	4.7	2.1%
Holopedium	161	163	3.6	0	81.9	36.5%
Ovig Holopedium	36.5	5.1	0.9	0	10.6	4.8%
Sidadae	0	0	0	0	0	0.0%
Cyclops	1.7	1.0	.07	7.6	2.7	1.2%
Copepod nauplii	5.7	0	1.0	4.8	2.9	1.3%
		Seasonal Mean Density, All Taxa			**225**	

DISCUSSION

The third year of study on the Falls, Gut Bay, and Kutlaku Lakes subsistence sockeye salmon project was successfully completed in 2003. We met all project objectives, but discontinued sockeye fry sampling in all lakes in 2003 because of technical difficulty in sampling for and estimating species apportionment.

At the completion of the third year of study, we have successfully estimated sockeye escapement and harvest for a third consecutive year at Falls Lake, and have supplemented that data with information on juvenile sockeye populations and rearing habitat in the lake. Of the project sites considered in this study, Falls Lake continues to receive the highest level of attention from the Kake community and fisheries resource managers because of the ongoing active subsistence fishery and low escapements into the lake.

Beginning in 2003, sockeye escapement into Falls Lake was no longer directly counted; instead, only those fish using the fish ladder were counted through a trap, and a mark-recapture study was used to estimate total escapement. According to the mark-recapture results, about 40% of the sockeye escapement used the fish ladder in 2003. Consistent estimates of the proportion of fish using the ladder will enable us to use the ladder counts as a reliable inseason index of escapement. The mark-recapture results fell well within our objective for precision, but the mark-recapture estimators using fish marked on the spawning grounds yielded a lower estimate of escapement, even after adjusting for spawners outside the study area. The weather delay in early September affected our ability to sample sockeye salmon moving into the spawning areas during the peak spawning period. This may have resulted in unequal capture probabilities or unequal mixing in some of the samples and led to biased estimates. Perhaps during the delay between 2 and 20 September, a number of spawners moved into the main inlet stream, spawned, and died during our absence, also violating the closure assumption for the Petersen estimate.

The harvest of 2,700 sockeye salmon in the Falls Lake terminal area was the largest on record. The sum of this harvest and the estimated escapement of 5,700 sockeye salmon is about 8,400 sockeye salmon; the harvest represented about 32% of this total. To address the concern that the harvest disproportionately targets the early part of the run, ADF&G instituted a mid-season closure from 7–13 July starting in 2003. Most of the subsistence fishing in 2003 occurred following this closure. Sockeye salmon were first counted through the trap on 11 July, during the mid-season closure, and by the close of the second part of the subsistence season on 20 July; escapement through the trap was about 540, or just under 10% of the total estimated escapement.

Even though subsistence harvest is clearly limiting escapement into Falls Lake, escapement may not be limiting sockeye production overall. Spawning habitat may be limited, or juvenile sockeye salmon may be limited by the freshwater rearing habitat, or both. Zooplankton prey populations were very low in Falls Lake in 2003 (Appendix D). This could be a result of low primary productivity in this oligotrophic lake (Conitz et al. 2002) or heavy grazing by sockeye fry or other predators. The small size of the *Daphnia*, a preferred prey of sockeye fry, could suggest grazing pressure. If prey availability is limiting juvenile sockeye populations in Falls Lake, it might show up in the age and size structure of these populations. Unfortunately, we don't have a fry estimate for 2003, and smolt estimates are not reliable since it appears we did not sample the early part of the emigration. The smolt sampled in 2003 were all age-1, but age-2 smolts typically emigrate earlier and we likely missed them. Even if juvenile sockeye are growing enough to emigrate Falls Lake at age-1, their average weight and length in 2003 were smaller than in many other Alaskan sockeye systems (Cartwright and Lewis 2004, Lewis and Cartwright 2002, Mazumder and Edmundson 2002, Edmundson and Mazumder 2001). Furthermore, in some previous years, the majority of sockeye smolt sampled were age 2 (Conitz et al. 2002). Physical factors were comparable in 2003 to previous years.

We estimated escapement for a second year and summarized lake habitat information for a third year in Kutlaku Lake in 2003. This system is currently not receiving as much subsistence fishing pressure as the Falls Lake system, however use and interest by the sport charter industry may be increasing. With no reliable information on Kutlaku Lake sockeye salmon populations prior to this project, it is difficult to draw conclusions from just two years' data; however, the escapement of several thousand fish documented in 2003, along with moderate zooplankton prey populations, suggest this system is productive and stable.

Having observed in Kutlaku Lake in 2002 that an early run spawns in the main inlet stream, while a larger late run spawns in the extensive shallow shoreline areas, we were able to sample both components of the escapement in 2003. The estimate of about 3,600 spawners in the inlet stream seemed high relative to the numbers counted in surveys of this small stream. It is likely some of the fish sampled off the mouth of this stream left to spawn in other areas. This would have violated the closure assumption for the study area and inflated the mark-recapture estimate (marks were effectively lost when marked fish moved out of the study area). Mark-recapture sampling conducted in one of the beach-spawning areas was more consistent and we could reasonably assume this to be a closed area. This study area had a seasonal weighted average of about 20% of sockeye salmon counted in visual surveys, which indicates that the study-area estimate of about 1,700 fish represented a whole-lake escapement of about 8,500, with a range of about 8,000– 9,000 spawners based on the 95% confidence interval of the mark-recapture estimate in study area 2.

Most sockeye spawners sampled in Kutlaku Lake had one freshwater year, as they did in all years of sampling in this lake since 1982 (Conitz and Cartwright 2003). Kutlaku Lake appears to support sockeye fry with a good zooplankton prey population. The abundance of *Daphnia* suggests the lake is not overgrazed, although their small size does indicate some grazing pressure.

Although we were unable to carry on research in Gut Bay Lake, this system should not be overlooked. Subsistence users continue to exploit the sockeye returns, and managers have expressed concern from time to time about harvest methods and amounts taken. Once again, very few spawners were observed in the lake during the single visual survey conducted in late August 2003.

CHAPTER 2 - THREE-YEAR FINAL REPORT

PROJECT BACKGROUND

Fisheries managers with ADF&G identified Falls and Gut Bay Lakes, from among more than a dozen small, island-based sockeye-producing systems in Southeast Alaska, as high priority areas for study because of their high-use subsistence fisheries, their relationship to nearby commercial fisheries, and the lack of available information on their sockeye salmon populations. Kake subsistence users also identified sockeye returns to these systems as among their highest priority resources, and further requested study of sockeye returns to Kutlaku Lake, added to the project in the second year.

Falls Lake currently receives the heaviest use by Kake subsistence fishers, but a number of people from Kake still regularly fish at Gut Bay and Bay of Pillars (Kutlaku). Archaeology and oral tradition show a long history of use of these areas by Kake people, but use patterns have changed over the last century in response to changing lifestyles and employment patterns in Kake. Before the 1900s, the Kake people were dispersed around the area between Frederick Sound and Chatham Strait, living in smaller villages and camps associated with particular salmon streams (Goldschmidt et al. 1998). Most of the people moved into the present-day Kake village when a government school was started there in 1905, and for most people, this meant being farther removed from their traditional fishing areas (Firman and Bosworth 1990). Some seasonal fishing camps were retained, and commercial fishing became a means of accessing traditional salmon resources for others. Widespread sharing of salmon and other subsistence resources among families in the community made it possible for those with commercial boats and permits to provide for the needs of almost everyone in the community. Recent changes in the commercial fisheries, however, have forced many small operators in Kake out of business; consequently, the designated subsistence fisheries at Falls, Gut Bay, and Bay of Pillars have become increasingly important for many households.

Previously no estimates of sockeye escapement or subsistence harvest levels specific to these systems were available on which to base management decisions. Biologists with ADF&G studied juvenile and adult sockeye salmon populations and lake habitat variables in Falls Lake during the 1980s, as part of a fertilization study (Koenings et al. 1983; Conitz et al. 2002). Results of that study provide some insight into the productivity of this system in recent times, as well as a range of escapements observed over a short time period. However, because data were collected only for a short period, ending when fertilization was stopped, results were inconclusive. Escapements during the six-years of study may or may not have been "typical" or average for this system. The study was not long enough to observe the returns from those juvenile sockeye salmon that were rearing in the lake during the years of study. Occasional aerial survey counts of sockeye salmon, and a single stream assessment conducted in the 1960s, were the only escapement information available for Gut Bay Lake. ADF&G conducted scale and length sampling of sockeye salmon in Kutlaku Lake from 1982–2000, estimating age and size compositions, and recording field observations. However, no attempt was made to estimate escapement or lake productivity.

In the Kake Sockeye Project, we placed priority on estimating adult sockeye escapements, and also estimated size and age distributions, populations of sockeye fry (including size and age distributions) and other small pelagic fish, secondary production (zooplankton, focusing on sockeye prey species), and physical characteristics of each lake. In addition, we estimated smolt size and age distribution and subsistence and sport harvests at Falls Lake. The results help fisheries biologists manage these systems for sustainable escapements with subsistence harvest opportunities for Kake residents.

OVERVIEW OF PROJECT OBJECTIVES AND METHODS

We reorganized this study with respect to study sites, at the request of the cooperating tribal governments in Kake, Angoon, and Hoonah following the 2001 season. Cooperators wanted the studies associated with each village to include sockeye systems that had traditional importance to people of that village. Besides the Falls Lake project, Kake had a second project involving Gut Bay, Kook, and Hoktaheen Lakes. Kook Lake is a traditional fishing area for Angoon, and was transferred to the Angoon sockeye project; Hoktaheen Lake is a traditional fishing area for Hoonah, and became part of a new Hoonah sockeye project. At the suggestion of the Organized Village of Kake, Kutlaku was added to the Kake Sockeye Project, and the two original projects were combined to include Falls, Gut Bay, and Kutlaku Lakes.

With only a few exceptions, we retained the original project objectives throughout the first three years of study. Objectives pertaining to estimation of escapement and the age-sex-length distribution of spawners were unchanged, with the exception of Gut Bay Lake, where sampling fish on the spawning grounds appeared to be impractical. Additional objectives for estimating Falls Lake escapement with the aid of a full or partial weir, estimating subsistence and sport harvests in the Falls Lake terminal area, and estimating smolt age and size composition, likewise remained the same throughout the project. Lake productivity sampling (light, temperature, dissolved oxygen, and zooplankton) was conducted in all three years, except for the third year at Gut Bay Lake. The objective of estimating sockeye fry populations in each lake was dropped in 2003 because of technical difficulties and changing priorities of the contracting agency.

We modified methods as necessary to adapt to the unique characteristics of each system and enable us to meet statistical criteria. We added a second mark-recapture study area in Kutlaku Lake in 2003, in response to the observation of at least two spawning groups in this system, one spawning earlier in the main inlet stream and the other spawning later around the lake shores. In 2003 we reduced the escapement sampling station at Falls Lake to a single trap at the top of the fish ladder, because the configuration of the falls on the outlet stream made it very difficult to construct a full weir. Daily fish counts, starting in 2003 at Falls Lake, have been only partial counts of escapement. We continued to back up the cumulative counts at the fish trap with a mark-recapture estimate, used from the beginning of the study in case fish were getting through the weir uncounted. We changed the fry sampling design in 2002 to allow for true replicate hydroacoustic transects in each lake section and for replicate trawl samples at depths and areas with the highest concentrations of fish (Conitz and Cartwright 2003).

We used the same statistical methods for data analysis throughout the first three years of the project without major changes, although some minor modifications and improvements were made in 2003 after thorough review by biometrics staff. Estimating sockeye fry populations is an exception, and modification of our methods is ongoing. The trawl samples used to apportion the acoustic targets by species were very small in lakes with low fish density, such as Falls. The sampling error associated with the species apportionment estimates is unknown and can be large because of the clumped distribution of small pelagic fish in the lake potentially unequal catchability of species, and small sample sizes. Our first approach was to increase the number of trawl samples, but this greatly increased the time needed for each survey. Consequently, we had to reduce the number of lakes surveyed each season. We eliminated the survey in Falls Lake because its fish density was so low no amount of towing would give us an adequate sample. The other lakes were not surveyed because they were lower on the priority list for study.

Mark-recapture estimates for beach-spawning sockeye populations, with a 95% confidence interval, were made using a modified version of the Jolly-Seber method as outlined in Schwarz et al. (1993) and further modified by ADF&G biometrics staff for small populations of sockeye salmon in beach-spawning areas (Conitz and Cartwright 2003; Cook 1998). In each lake, only a portion of the spawning population was sampled, within a study area defined by physical features of the lake shoreline and the tendency of sockeye spawners to aggregate within specific locations. A whole-lake estimate of escapement could be obtained by estimating the proportion of sockeye spawners in each lake that were available for sampling within the study area and expanding the study-area estimate by this proportion. We have attempted to do this by using observer counts of fish in the study area and in other parts of the lake. The only variation in observer counts that we can quantify is the difference in counts between individual observers, yet other factors, such as water depth and clarity, weather, and behavior of fish, could be more significant sources of observational error. Therefore the proportion of sockeye spawners within the study area is considered a rough estimate, to allow for us to re-scale the study-area estimate for comparison purposes and to indicate trends. No attempt was made to estimate the non-sampling (between observer) error or the magnitude of the observational error of this proportion, and the whole-lake extrapolation. In Falls Lake, we had the unique opportunity to compare reliable weir-based estimates of escapement with mark-recapture estimates of fish on the spawning grounds for three years.

THREE-YEAR RESULTS AND DISCUSSION

We would like to know what factors limit sockeye salmon production in Falls, Gut Bay, and Kutlaku Lakes. Fishery managers must ensure adequate escapement before opening or extending harvest seasons, but have not known the effects of various levels of escapement on production in these lakes. After three years of study at Falls Lake, possible trends are beginning to emerge. Only two years of study at Kutlaku Lake gave us a snapshot of current productivity, but not enough information to start looking at trends. Unfortunately, we were unable to estimate escapement in Gut Bay Lake using mark-recapture methods because of small numbers and highly dispersed spawning behavior of sockeye salmon on the spawning grounds. Furthermore, we decided flights into this small steep basin were not safe in frequent bad weather. We recommend Gut Bay Lake be considered for a weir in the future.

Falls Lake

In the late 1990s, ADF&G fishery managers, concerned about an increase in reported harvests of Falls Lake sockeye salmon, decided some limit was needed. At that time, they had no up-to-date estimates of sockeye escapement into Falls Lake, but escapement counts from the weir in the 1980s were small, averaging about 2,500 sockeye salmon annually (Conitz et al. 2001). Reported harvests of Falls Lake sockeye salmon averaged about 1,000 salmon annually between 1993 and 2000, compared with reported harvests of just a few hundred fish annually in 1985–1992 (Appendix A). These harvest numbers, reported by permit-holders without independent verification, were not necessarily an accurate assessment of total harvest; one study indicated that fishers tended to underreport their catch on ADF&G subsistence permits (TRUCS 1988). Therefore, they were interpreted as a conservative estimate of harvest. To limit total harvest, fishery managers somewhat arbitrarily chose to close the season at a time when about 80% of the harvest usually occurred, based on reported daily harvest numbers from permits for years 1985–1997. As a result, the Falls Lake subsistence fishery, previously open from 1 June–15 August, closed on 20 July during the 1999–2001 seasons.

In on-site harvest surveys, we estimated subsistence fishers harvested about 2,000–2,700 fish in 2001–2003[1], regardless of the total return (harvest + escapement) to the terminal area (Table 25). The proportion of the total return harvested in the subsistence fishery varied widely during the three years of this study, suggesting that Falls Lake fishers were capable of harvesting large number of fish regardless of the strength of the run (Table 24). For example, in 2002 the escapement was about half that in 2001, but the terminal harvest was about 25% higher than in 2001.

Table 25.–Comparison of Falls Lake terminal area sockeye harvest (subsistence and sport) and escapement estimates. Total return to the terminal area is the sum of terminal area harvest and escapement.

Year	Total Terminal Area Harvest	Escapement	Harvest + Escapement	Percent Harvested
2001	2,000	2,600	4,600	43%
2002	2,600	1,100	3,700	70%
2003	2,700	5,700	8,400	32%

By observing the daily timing of the Falls Lake fishery and of escapement into the lake via the fish ladder, managers attempted to protect escapement by adjusting subsistence fishery time and area regulations. Noting that early escapement was lacking in 2001, they sought to distribute harvest timing more evenly throughout the run. In 2001, average daily harvest was 86 sockeye salmon from 29 June–20 July, and no sockeye salmon entered the lake until after fishery closure on 20 July (Figure 9). In 2002, ADF&G managers recommended closing a 300 ft. area in front of the falls to reduce efficiency and hopefully spread the harvest over a longer period. Representatives from Organized Village of Kake agreed to this restriction, but requested an increase in the daily possession limit and an extension of the season because of the cost and difficulty of traveling from Kake to Falls Lake. Consequently, the daily possession limit of 10 sockeye salmon was amended to a possession/annual limit of 50 sockeye salmon per household and the 2002 season was extended to the end of July. In spite of the changes, average daily harvest in 2002 was 104 sockeye salmon from 29 June–23 July, and escapement remained very low during this time (Figure 9). ADF&G closed the subsistence fishery by emergency order on 24 July, 2002. Average daily harvest may have been higher in 2002 than in 2001 because of good weather in July, allowing more people to easily cross Chatham Strait in small skiffs, and also because of the higher possession limit. In 2003, ADF&G managers instituted a closure from 6–14 July in hopes more sockeye salmon would escape into the lake earlier in the season. By the close of the 2003 subsistence fishery, about 25% of the escapement had entered the lake, and average daily harvest was 118 sockeye salmon from 29 June-20 July (Figure 9). Average daily harvest was probably higher again in part because of 50-fish possession limit, and also because more sockeye salmon returned to Falls Lake in 2003.

[1] Comparing estimates from the on-site surveys with reported harvests on ADF&G subsistence permits confirmed some under-reporting of actual harvest on permits. Permit-holders' reports were 36, 31, and 10 percent lower than on-site estimates in 2001, 2002, and 2003 respectively. The increased daily possession limit implemented in 2002 may have helped to reduce the gap between reported and estimated harvests in 2003. However, even the on-site estimates are probably conservative because fishers also appeared to underestimate their true catch during on-site interviews (Falls Lake crew, personal communication 2002, 2003).

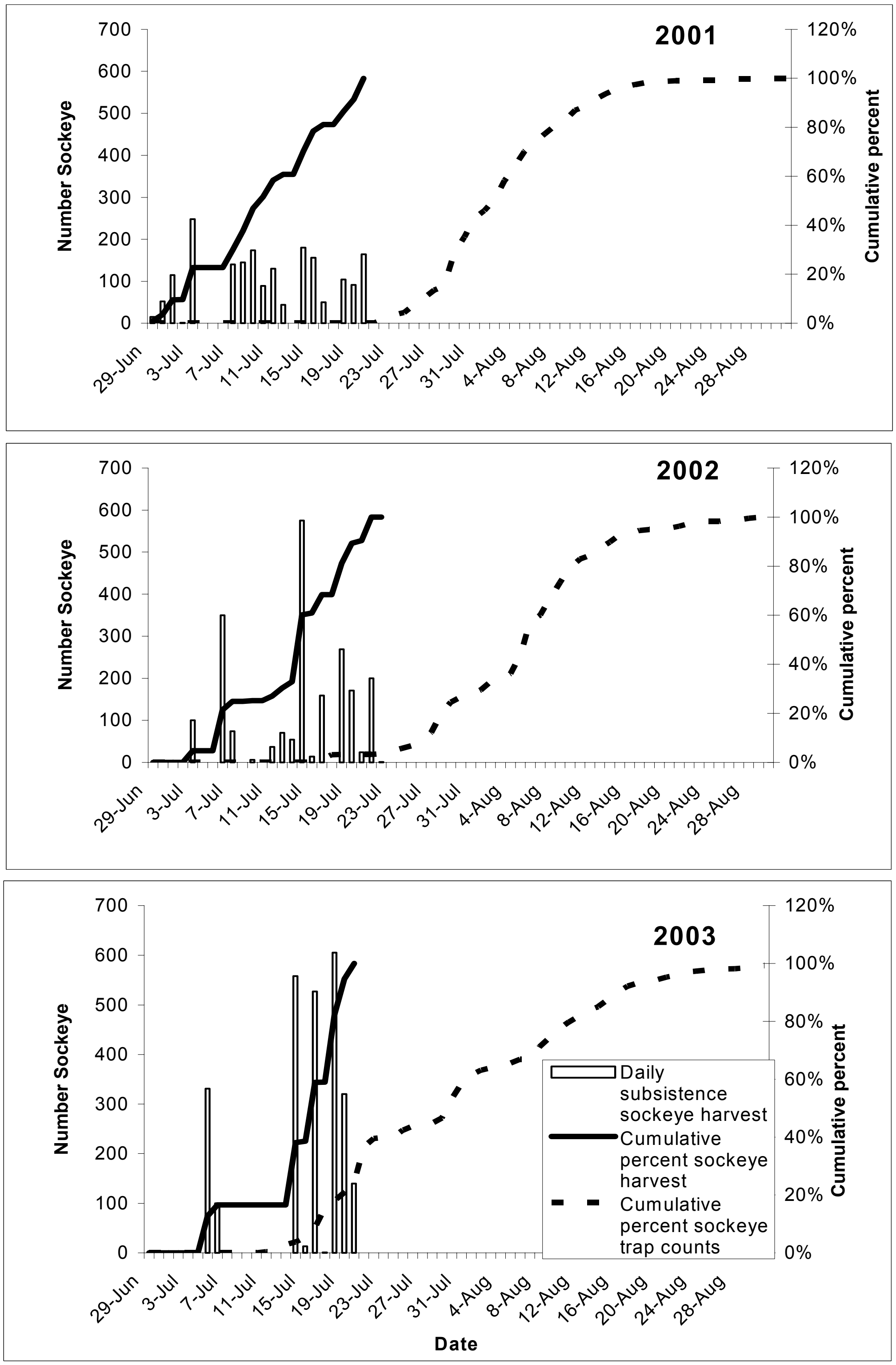

Figure 9.–Falls Lake subsistence fishery harvest by day, the cumulative harvest throughout the season and the cumulative percent of sockeye salmon entering the fish ladder as escapement in 2001, 2002 and 2003.

At first glance, the split season in 2003 appeared to effectively allow fish to escape into the lake during the fishery because 24% of the escapement entered the lake during the subsistence fishery (Figure 9). However, only 85 sockeye salmon entered the lake via the fish ladder during the mid-season closure (Table 26; Appendix C). No sockeye salmon entered the trap for the first four days of the closure but the number steadily increased the last three days (Table 26). Assuming 40% of sockeye salmon entered the lake via the fish ladder (see mark-recapture result section), roughly 200 fish entered the lake during the fishing closure. Escapement during the closure may have been low because a large number of fish (about 400) were harvested just before the closure, the run was still building, and the closure was too short.

Table 26.–Daily counts of sockeye salmon entering the trap at the top of the fish ladder during the closure of the subsistence fishery in 2003.

Date	Number of sockeye salmon through trap
7/7	0
7/8	0
7/9	0
7/10	0
7/11	8
7/12	13
7/13	64

Because of the short season for both harvest and escapement into this small system, we recommend planned, systematic trials of several different management scenarios while a monitoring project is in place. Ideally, season and area regulations for the Falls Lake subsistence fishery could be established to provide sufficient harvest opportunities and ensure adequate escapement into the lake without requiring yearly inseason monitoring.

Although high harvest rates relative to escapement initially suggested Falls Lake sockeye production may be limited by escapement in some years, the relationship of escapement to juvenile production indicates other factors may limit production in this lake environment. Specifically, we would expect an increase in adult sockeye spawners to produce more sockeye fry the next year. Fry numbers do not appear to reflect numbers of adult spawners in the previous year (Table 27). In three out of four years with paired adult escapement and fry estimates (parent years 1982, 1983, and 2001), escapements ranging from 1,700 to 3,600 adults produced roughly similar numbers of offspring (about 20,000 fry), but the low escapement in 1984 produced almost five times that number of fry (95,000) the next year. This large fry population was produced during the second year of a lake fertilization experiment. Most of those fry did not smolt until age-2, an indication of food limitation at that population density. Furthermore, the total fry population in the lake in 1985 included about 33,000 age-1 fry that remained for a second year in the lake, in addition to the 21,000 age-0 fry (Tables 27 and 28). Competition between the larger age-1 fry and the age-0 fry could have limited the number (survival) of age-0 fry in 1985 or slowed their growth. Fertilizer application in 1983–1985 almost certainly confounds the observed relationship between escapement and fry production in Falls Lake (see Conitz et al. 2002, for details on fertilizer application and freshwater variables estimated during the 1980s). With complete data (parents-fry-smolt age) for only one brood year not influenced by fertilization, it is not possible to try and separate effects of fertilization from other influences on juvenile production, but it does appear the fry population can become food limited even with fertilization. We note sockeye fry were not stocked in Falls Lake, which would have introduced even more confounding effects.

Table 27.–Comparison of Falls Lake spawning populations, numbers of age-0 fry the following year, and percent smolting at age 1 two years later, for years with estimates available. Shading indicates years in which the lake was fertilized (1980s estimates from ADF&G Div. of Commercial Fisheries unpublished data, also cited in Conitz et al. 2002).

Parent year	Parent year escapement	Number age-0 fry (one year later)	Percent age-1 smolt (two years later)
1981	1,300	na	na
1982	1,700	27,000 (26-Oct)	28
1983	1,700	95,000 (17-Jul)	5
1984	3,600	21,000 (12-Sep)	na
1985	2,600	na	-
2000	na	67,000 (18-Sep)	84
2001	2,600	19,000 (24-Sep)	na[1]
2002	1,100	na	-

[1]Smolt sampling in 2003 did not capture the early run, so an age distribution estimate is not available.

Estimated zooplankton biomass in Falls Lake is low, and may limit survival and growth of sockeye fry. Zooplankton biomass showed a strong negative relationship in 1985 (with fertilization) and 2002 (no fertilization) to high fry abundance (98,000 and 75,000) in the preceding year, but this relationship did not apply specifically to *Daphnia* biomass (Table 28). *Daphnia* biomass, already very low, did not drop further in 1985 and 2002. Overall, *Daphnia* biomass was higher in the 1980s, before and during fertilization, than it was almost 20 years after fertilization, even though the ranges of sockeye fry and total zooplankton populations were roughly similar in the two time periods (Table 28). Large-bodied *Daphnia* is a preferred prey for sockeye fry, and can give an indication of how the sockeye population may respond to changes in other trophic levels (Mazumder and Edmundson 2002). Low *Daphnia* biomass in 2001–2003 suggests increasing escapement may not increase overall sockeye production in Falls Lake because of food limitations.

Table 28.–Summary of lake habitat and fry population data collected in Falls Lake, 1981–1986 and 2001–2003. Falls Lake was fertilized from 1983–1985, as denoted by the shading.

Year	Number of sockeye fry	Zooplankton biomass ($mg \cdot m^2$) Total	*Daphnia*	Number of sticklebacks	Euphotic Zone Depth
1981		101	4		8.0
1982		45	3		8.4
1983	32,000	115	5	19,000	9.5
	98,000	123	3	5,000	8.5
1985	54,000	15	4	18,000	9.5
1986		25	5		
2001	75,000	105	0	0[1]	9.7
2002	19,000	28	1	12,000	10.3
2003		29	2		9.6

[1]No sticklebacks were caught in a trawl sample of 94 fish, but our observations suggest that some sticklebacks were, in fact, present.

Presence of sticklebacks in Falls Lake adds unknown restrictions on sockeye fry production because of competition. As competitors with juvenile sockeye salmon, sticklebacks may limit juvenile sockeye production when food resources are low, by consuming some of the same prey base (Beauchamp and Overman 2003). Stickleback numbers were high, relative to sockeye fry numbers, in three out of the five years studied (Table 28). Numbers of sticklebacks and sockeye fry are estimated from total hydroacoustic targets by their respective proportions in trawl samples. Trawl sample sizes were small in Falls Lake (Conitz and Cartwright 2003, Conitz et al. 2002; also unpublished data, ADF&G Div. of Commercial Fisheries). We do not have an estimate of sampling error for the trawl samples, but it could be high and the species apportionments must be considered very rough estimates.

Physical characteristics of the lake can influence primary production and, to a lesser extent, secondary (zooplankton) and tertiary (sockeye fry) production. The euphotic zone depth, was similar between the 1980s and 2001–2003; although it was on average about 1 m deeper in the more recent years (Table 28). Plumes of glacial sediments were observed at the mouth of the main inlet stream in Falls Lake in 2001, but to a lesser degree or not at all in 2002–2003. Temperature profiles do not appear different between the 1980s and the 2000s, but have not been thoroughly analyzed with respect to their significance to production (Conitz and Cartwright 2003, Conitz et al. 2002, Koenings et al. 1983, unpublished data, ADF&G Div. of Commercial Fisheries). With limited information available, it is not clear these physical factors in the Falls Lake freshwater environment are as important as effects of sockeye fry abundance and grazing.

If spawning habitat is limited, sockeye fry production will not respond positively to increased escapement. Falls Lake has few suitable spawning beaches and only short stream sections accessible to spawners. Because of the steep, glaciated terrain surrounding the lake, sudden and dramatic changes along the beaches and in the stream channels are frequent, relative to salmon population history in this system. We observed a major channel shift in at the mouth of one of the inlet streams between 2001–2003, which has caused elimination or relocation of a large part of the beach spawning habitat in the lake.

Comparing lake habitat, fry, smolt, and escapement data collected in the 1980s with results from the 2001–2003 study raises some questions, with a few clues but no definitive answer, about what is limiting sockeye production in Falls Lake. Possible effects of lake fertilization from 1983–1985 confound results from those years, and most data collection did not continue beyond the last year of fertilization. The continuation of research at Falls Lake in 2004–2006 will allow us to examine the response of the Falls Lake system to climatic and escapement variability over an uninterrupted six-year period without fertilization or other enhancement. With continued study, we hope to determine more closely which factors do limit production and provide biologically-based guidelines for setting sustainable escapement levels and maximizing subsistence harvest opportunities.

Kutlaku Lake

Subsistence fishing in the Bay of Pillars, targeting Kutlaku Lake sockeye salmon, is currently far less popular with Kake residents than at Falls Creek. Various reasons have been given for this difference, but whatever the reason, Kutlaku Lake sockeye stocks are apparently not heavily exploited in the subsistence fishery, compared with other systems. The total annual reported harvest was under 400 sockeye salmon between 2001–2003. In 2002, our "best guess" at total escapement was 10,000 sockeye salmon (range 8,900–13,000), based on an estimate of 1,300 sockeye salmon spawning early in the season in the inlet stream and representing about 13% of total escapement (Conitz and Cartwright 2003). In 2003, we extrapolated a total escapement of about 8,500 sockeye salmon (range 7,500–9,000) from an estimate of 1,700 fish spawning later in the season along the lake shoreline and representing about 20% of total escapement. Although these escapement estimates are rough, total reported subsistence harvests in 2002 and 2003 clearly represented only a few percent of the total sockeye returns to the terminal area at the head of Bay of Pillars.

Examination of our estimates of sockeye fry and zooplankton populations suggests Kutlaku Lake is a productive system without obvious rearing limitations. In the two years for which we have estimates, fry population levels remained about the same, and fry density was very high compared with other Southeast Alaska lakes in 2002 (Appendix E). At the same time, zooplankton populations have increased over the three years of this study. The very large increase in total zooplankton biomass in 2003 may not be significant in terms of sockeye fry habitat because a large proportion of that biomass was *Holopedium gibberum*, a large gelatinous species that has very little caloric value. However, the increase in *Daphnia* sp. biomass was almost as dramatic and likely much more significant for sockeye fry. *Daphnia* biomass in Kutlaku Lake was relatively high compared with other sockeye-rearing lakes in Southeast Alaska in all three years, 2001–2003, but was especially high in 2003 (Table 29; Appendix D). Grazing pressure is indicated by the small average size of *Daphnia* individuals, but overall, zooplankton populations in Kutlaku Lake, including *Daphnia*, did not appear to limit production of sockeye salmon at the levels observed. The relatively large average size (1.1 g) of age-0 sockeye fry sampled in trawl tows (Appendix E), and the predominance of age-0 fry, also suggest food did not limit sockeye fry production. Although age distributions from the trawl samples may not be reliable due to avoidance behavior in larger and older fry, age composition of adults in the escapement shows most Kutlaku sockeye salmon smolt at age 1 (Table 14 in this report; Conitz and Cartwright 2003).

Table 29.–Summary of lake habitat and fry population data collected in Kutlaku Lake in 2001–2003.

		Total zooplankton seasonal means[2]		*Daphnia* seasonal means			Fry population
Year	EZD[1] (m)	Biomass ($mg{\cdot}m^{-2}$)	Density ($1000s{\cdot}m^{-2}$)	Biomass ($mg{\cdot}m^{-2}$)	Density ($1000s{\cdot}m^{-2}$)	Av. length (mm)	Estimated total
2001	7.4	177	117	32	15,000	0.62	102,000
2002	8.1	131	81	35	27,000	0.55	115,000
2003	7.9	618	223	80	68,000	0.52	

[1]EZD = euphotic zone depth, depth at which light intensity is 1% of that just below surface

[2]seasonal means are means of two stations sampled at least four times between spring and fall

Gut Bay Lake

Although we were able to estimate sockeye fry populations, zooplankton abundance, and physical characteristics of the lake, we were unable to estimate sockeye escapement into Gut Bay Lake. Conducting mark-recapture sampling in this lake was difficult, because of the sparse and highly dispersed distribution of sockeye spawners along a steep shoreline with dense overhanging vegetation; furthermore, we faced unsafe conditions for flying into this small narrow drainage. In lieu of mark-recapture estimates, we decided to use visual survey counts of sockeye spawners as a baseline for examining year-to-year differences in escapement. The excellent visibility of the nearshore area and the even dispersal of sockeye spawners in this area made it possible to accurately count the number of spawners present. In 2001 and 2002, survey counts in mid-September (38 and 48) and early October (146 and 158) were similar, suggesting sockeye escapement was similar in those two years (Conitz and Cartwright 2002, 2003). However, in 2003 we discontinued all study, after conducting one survey in late August, due to the problem of unsafe access.

The few survey counts we have, along with harvest information from returned permits, suggest small sockeye populations returning to Gut Bay Lake. Surveys counts in 2001–2003 never exceeded 200 spawners on any given date. However, we do not know the residence or turnover time of sockeye salmon on the spawning grounds, which would be necessary to estimate escapement from survey data. Additional sockeye salmon may spawn in deep upwelling areas where steep inlet streams enter the lake, below the depth visible to observers. Reported subsistence harvests during the period of this study ranged from a low of 121 sockeye salmon in 2002 to a higher total of 577 sockeye salmon in 2001 (Appendix A). However, we have seen at Falls Lake and elsewhere that harvest is consistently under-reported in the permit system (Conitz et al. 2002: Conitz and Cartwright 2003; Cartwright and Lewis 2004). In the absence of reliable harvest and escapement information, fishery managers maintained conservative limits on harvest in Gut Bay. The possession limit for sockeye salmon from this system was held at 10 fish despite the long distance subsistence fishers must travel from Kake to Gut Bay. Managers also set the fishing boundary farther from the creek mouth to prevent fishers from blocking the entire outlet stream (B. Davidson ADF&G, personal communication 2003).

Apparent low sockeye returns to Gut Bay Lake were contradicted by high fry estimates in the lake (Conitz and Cartwright 2002; Appendix E). Perhaps we could attribute this seemingly contradictory information to large and unknown sampling error in the fry estimates. However, zooplankton population estimates for Gut Bay Lake were the lowest among other Southeast Alaska sockeye rearing lakes studied in 2001–2003 (Appendix D). High sockeye fry populations and very low zooplankton populations could indicate that sockeye production in Gut Bay Lake is controlled by zooplankton production and the system is food-limited. The average weight of age-0 sockeye fry sampled in Gut Bay Lake in 2002 was very low (0.5 g in late August) compared to other systems (Appendix E). The zooplankton standing crop biomass, averaging only about 30 $mg \cdot m^{-2}$ over the 2001 and 2002 growing seasons, is well below a starvation threshold of 100 $mg \cdot m^{-2}$ postulated by Edmundson and Mazumder (2001) in a study of other sockeye-rearing lakes in Alaska.

Physical factors could influence sockeye production in the lake, even with low numbers of spawners, by increasing fry survival rates. Temperature, combined with food availability and fish density, were the most significant predictors of age-1 smolt size (thus, fry growth) in an evaluation of data from 36 sockeye rearing lakes in Alaska (Edmundson and Mazumder 2001). Temperature affects metabolism and growth of fish in a number of ways, but is difficult to evaluate because of the complexity in, and interactions between, lake temperature profiles and fish movement in the water column. Seasonal temperature profiles and maximum summer and fall temperatures were similar in Gut Bay Lake to those of other sockeye-rearing lakes in Southeast Alaska having very different physical characteristics. Light penetration is a major factor influencing primary production (Koenings and Burkett 1987), and Gut Bay Lake is very clear, with one of the deepest euphotic zones among sockeye-rearing lakes in Southeast Alaska (Conitz and Cartwright 2002 and 2003). However, because of its small surface area, the total photosynthetic volume of Gut Bay Lake (surface area x euphotic zone depth) is very small. The physical characteristics of Gut Bay Lake do not appear, in themselves, to explain the relationship between apparently low adult and high fry abundances.

Our evaluation of factors influencing sockeye production in Gut Bay Lake is limited by lack of reliable escapement estimates, and uncertainty in our fry estimates. A weir on the Gut Bay Lake outlet stream would enable us to obtain reliable escapement estimates. In addition, evidence of rearing limitations, in the small size of sockeye fry and very low zooplankton biomass, should be followed up with an assessment of smolt size and age.

CONCLUSIONS

Falls, Gut Bay, and Kutlaku Lakes are distinct morphologically and biologically. What they have in common is that the three together provide Kake residents with most of the sockeye salmon they need for subsistence. In the absence of sockeye-producing streams close to the village, Kake residents travel considerable distances to reach these three systems, and these are the only productive sockeye systems within a comparable radius from Kake.

Of the sockeye systems in the area around Kake, Falls Lake is the most heavily utilized for subsistence fishing. Researchers and contracting agencies have given Falls Lake the highest priority in the Kake sockeye project, with additional objectives including inseason monitoring of the subsistence harvest. Results from 2001–2003 indicate the terminal area sockeye harvest can equal or exceed escapement in this system. Although harvests have increased in recent years, escapements in 2001–2003 were within the range of escapements documented in the 1980s (Conitz et al. 2002). Because it may be limited in both rearing and spawning habitat, the lake may not support larger juvenile populations. Fishery managers are currently using inseason and postseason results from the Falls Lake study to attempt to maintain the balance between harvest and escapement such that harvest does not exceed 50% of total terminal area returns (subsistence and sport harvest plus escapement). In order to maintain this level of management, we need a continuing time-series of escapement and harvest estimates for this sockeye stock. We also need continuing estimates of juvenile sockeye and prey populations in order to understand the relationship between escapement and production in this system. Given observed patterns and practices in subsistence fishing in Kake, the village will continue to depend heavily on Falls Lake sockeye salmon to fulfill their subsistence needs. Our continuing research will support the intensive management necessary to ensure this system can provide enough sockeye salmon for Kake residents for generations to come.

Subsistence fishing pressure appeared to be far less at Bay of Pillars (Kutlaku) and Gut Bay during the three years of this study, although subsistence harvest was not directly monitored in those systems. We were reasonably successful in estimating escapements and freshwater productivity in Kutlaku Lake for two years (plus an additional year of zooplankton sampling), and concluded sockeye populations were neither escapement nor food limited during this short period. Sockeye escapement, fry population, and zooplankton population estimates for Kutlaku Lake in 2002 and 2003 are of limited usefulness to fishery managers because of the short duration of the study. However, these are the only available estimates of sockeye populations in the Kutlaku Lake system. Disagreement over whether the adult sockeye salmon returns to Kutlaku Lake are a conservation concern continues to surface in the form of proposals to the Federal Subsistence Board. Hence, reinstatement of a research study in this system may be beneficial in resolving this conflict. We were unsuccessful in estimating sockeye escapement into Gut Bay Lake, but have some evidence of either low escapements or rearing-habitat limitations, or both, in this lake. We recommend the use of a weir in the outlet stream of Gut Bay Lake to obtain reliable escapement information, as yet unavailable for this system. Without continued study, conservative management of subsistence fishing in these systems will be necessary, and managers will have to rely on permit-holders' reported harvests to monitor sockeye harvest levels. Any problem with these sockeye stocks unrelated to subsistence fishing may go undetected, unless severe enough to affect success in the already limited subsistence fishery.

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APPENDICES

Appendix A.–Sockeye harvest, number of permits, and average harvest per permit at Falls Creek, Gut Bay, and Bay of Pillars (Kutlaku), reported by subsistence permit-holders and compiled in the ADF&G Div. of Commercial Fisheries database, 1985–2002.

Year	Stream	Permits	Sockeye	CPUE	Stream	Permits	Sockeye	CPUE	Stream	Permits	Sockeye	CPUE
1985	**Falls Ck**	2	17	9	**Gut Bay**	37	339	9	**Kutlaku**	38	812	21
1986		3	30	10		59	572	10		32	750	23
1987		3	30	10		22	211	10		50	1312	26
1988		24	338	14		39	419	11		48	969	20
1989		26	390	15		29	649	22		36	784	22
1990		16	149	9		16	182	11		27	593	22
1991		10	122	12		12	128	11		37	813	22
1992		34	550	16		46	765	17		63	1375	22
1993		51	1012	20		52	795	15		23	516	22
1994		51	911	18		32	432	14		24	629	26
1995		56	976	17		38	490	13		11	238	22
1996		70	1229	18		41	488	12		33	842	26
1997		68	977	14		23	287	12		33	648	20
1998		62	1101	18		53	732	14		33	791	24
1999		75	1020	14		26	272	10		46	984	21
2000		59	798	14		37	419	11		15	200	13
2001		84	1290	15		47	577	12		8	130	16
2002		62	1795	29		12	121	10		8	194	24
2003		63	2434	39		20	245	12		22	366	17
average, 1985–1993:		19	293	13		35	451	13		39	880	22
average, 1994–2003:		65	1253	20		33	406	12		23	502	21

Appendix B.–Commercial harvest of sockeye salmon in southern Chatham Strait, by sub-district (locations of sub-districts shown in Fig. 2). Average annual harvests for years with commercial harvest are shown, by decade, for each sub-district and all sub-districts combined.

	Sub-District (of district 109)							
Year	**10**	**20**	**51**	**52**	**61**	**62**	**63**	**All Sub-Districts**
1970	2	71	1,668	174	211	44	1	2,171
1971		205	1,209	490	153	285	2,303	4,645
1972		12	617	24		200	240	1,093
1973		6	0	1	139	164	0	310
1974		0	1,492	10	964	1,626	740	4,832
1975	2							2
1976					0	0		0
1977	300					46		346
1978						554		554
1979	139	10,564	162	35	4	857	133	11,894
1980	602	11	175	6	16	110	0	920
1981	44	134	299	0		48		525
1982	2,964	2,994	1,013	0		2		6,973
1983	191	480			16	43	0	730
1984	419	1,473	407	12		318	22	2,651
1985	330	3,622	9,242	25		673	34	13,926
1986				29	211	1,756		1,996
1987	4	1,794	4			10		1,847
1988	0	767	1,132	167		3,769	43	5,878
1989	4	1,639	5,409			183		7,241
1990	119	2,568	3,506	115	606	318	428	7,699
1991	47	2,221	2,563		1,321	359		6,522
1992	2,604	2,647	9,539	13	1,724	1,290	829	18,888
1993	2,880	10,994	12,027		2,524	1,639		30,134
1994	2,374	10,696	9,401	78	11,901	1,217	119	35,811
1995	2,506	1,288	2,859		15,853	1,243	386	24,151
1996	626	934	4,267	48	403	506	10	6,804
1997	1,507	4,062	5,447	6	440	13		11,498
1998	553	3,741	6,691	182	6,012	368		17,554
1999	166	3,342	5,893	84	847	99	90	10,543
2000		1,305	4,482	134	168	1,307		7,396
2001	119	410	35,122	346	4,960	863	56	41,879
2002	6	483	8,145	67	1,917	514	12	11,144
2003	54	253	18,492	554	5,369	1,893	11	26,629
Decade Averages*								
1970–1979	111	1,810	858	122	245	420	570	4,135
1980–1989	506	1,435	2,210	34	81	691	20	4,978
1990–1999	1,338	4,249	6,219	75	4,163	705	310	17,061
2000–2003	60	613	16,560	275	3,104	1,144	26	21,782
All Years	714	2,370	5,402	108	2,424	676	273	11,967

*averages of years with reported harvests only

Appendix C.–Daily and cumulative counts of sockeye and coho adult salmon [a] at Falls Lake weir/trap, daily subsistence harvests and associated water levels and water and air temperatures for 2003.

	Sockeye Salmon		Coho Salmon		Physical Data		Daily Sockeye Subsistence Harvest
Date	Daily	Cumulative	Daily	Cumulative	Water level (mm)	Water temp (°C)	
Trap operational from 10 June; no fish counted during June							0
29-Jun							0
30-Jun					250	12	0
1-Jul	0	0	0	0	244	13	0
2-Jul	0	0	0	0	244	12	0
3-Jul	0	0	0	0	250	12	0
4-Jul	0	0	0	0	268	12	0
5-Jul	0	0	0	0	244	12	331
6-Jul	0	0	0	0	238	14	100
7-Jul	0	0	0	0	219	16	0
8-Jul	0	0	0	0	213	15	0
9-Jul	0	0	0	0	213	15	0
10-Jul	0	0	0	0	213	15	0
11-Jul	8	8	0	0	213	16	0
12-Jul	5	13	0	0	213	15	0
13-Jul	51	64	0	0	219	17	0
14-Jul	19	83	0	0	238	18	558
15-Jul	33	116	0	0	213	15	13
16-Jul	80	196	0	0	213	14	527
17-Jul	152	348	0	0	213	15.5	1
18-Jul	52	400	0	0	213	14	605
19-Jul	65	465	0	0	207	13	320
20-Jul	76	541	0	0	226	17	140
21-Jul	272	813	0	0	305	14	
22-Jul	66	879	0	0	256	15	
23-Jul	7	886	0	0	226	15	
24-Jul	5	891	0	0	189	16	
25-Jul	52	943	0	0	183	16.5	
26-Jul	30	973	0	0	183	16	
27-Jul	12	985	0	0	177	15	
28-Jul	9	994	0	0	171	15	
29-Jul	41	1035	0	0	180	15	
30-Jul	150	1185	0	0	183	16	
31-Jul	115	1300	0	0	183	16	
1-Aug	65	1365	0	0	177	15	
2-Aug	37	1402	0	0	177	15	
3-Aug	19	1421	0	0	177	16	
4-Aug	17	1438	0	0	174	14	
5-Aug	18	1456	0	0	177	16	
6-Aug	31	1487	0	0	165	17.5	
7-Aug	0	1487	0	0	171	14	

Appendix C (continued)- Daily and cumulative counts of sockeye and coho adult salmon [a] at Falls Lake weir/trap, daily subsistence harvests and associated water levels and water and air temperatures for 2003

	Sockeye Salmon		Coho Salmon		Physical Data		Daily Sockeye Subsistence Harvest
Date	**Daily**	**Cumulative**	**Daily**	**Cumulative**	**Water level (mm)**	**Water temp (°C)**	
8–Aug	95	1582	0	0	171	18	
9–Aug	69	1651	0	0	171	17	
10–Aug	70	1721	0	0	171	17	
11–Aug	52	1773	0	0	171	17	
12–Aug	45	1818	0	0	171	17	
13–Aug	43	1861	0	0	171	17	
14–Aug	29	1890	0	0	177	16.5	
15–Aug	56	1946	11	11	390	16.5	
16–Aug	57	2003	18	29	366	16.5	
17–Aug	45	2048	10	39	305	16.5	
18–Aug	22	2070	5	44	262	16	
19–Aug	11	2081	0	44	201	16	
20–Aug	15	2096	2	46	183	16	
21–Aug	20	2116	0	46	219	16	
22–Aug	15	2131	0	46	213	14.5	
23–Aug	23	2154	0	46	198	14.5	
24–Aug	10	2164	1	47	183	13.5	
25–Aug	6	2170	0	47	171	15.5	
26–Aug	3	2173	1	48	168	15	
27–Aug	5	2178	3	51	158	15	
28–Aug	5	2183	3	54	152	14	
29–Aug	6	2189	1	55	149	15	
30–Aug	7	2196	12	67	320	15	
31–Aug	13	2209	20	87	366	14	
1–Sep	4	2213	3	90	439	13	
2–Sep	2	2215	1	91	573	13	
3–Sep	3	2218	1	92	390	12	
4–Sep	4	2222	6	98	311	13.5	
trap removed on 5 Sept.							
Season Totals		2222		98			2595

[a] Other species: pink salmon – 113; chum salmon – 3; Dolly Varden char – 33

Appendix D.–Seasonal mean biomass of all zooplankton and of *Daphnia* sp. and mean length of *Daphnia* sp. (weighted by abundance) in selected sockeye-producing lakes in Southeast Alaska.

	2001 Seasonal mean biomass (mg ·m^2)				2002 Seasonal mean biomass (mg ·m^2)				2003 Seasonal mean biomass (mg ·m^2)		
Lake	**All zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**	**Lake**	**All zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**	**Lake**	**All Zooplankton**	***Daphnia* sp.**	**Mean length *Daphnia* (mm)**
Sitkoh	651	93	0.73	Hoktaheen	651	20	0.91	Kutlaku	618	84	0.51
Kanalku	371	119	0.95	Sitkoh	579	201	0.79	Tumakof	500	0	0.66
Salmon Bay	364	85	0.94	Tumakof	496	2	0.65	Klawock	431	37	0.97
Hoktaheen	328	32	0.87	Klawock	499	16	0.90	Kanalku	371	78	0.75
Kook	299	37	0.87	Kanalku	420	137	0.75	Salmon Bay	351	32	0.93
Luck	234	17	0.86	Kook	315	52	0.80	Klag	316	7	0.68
Klawock	217	12	0.94	Luck	316	18	0.77	Luck	201	6	0.73
Klag	181	4	0.65	Klag	222	5	0.97	Thoms	163	7	0.55
Kutlaku	177	32	0.63	Salmon Bay	205	19	0.75	Eek	147	0	na
Falls	104	0	0.66	Kutlaku	131	35	0.51	Hetta	45	2	0.68
Thoms	144	9	0.60	Thoms	119	7	0.57	Falls	29	1	0.66
Hetta	34	0	0.63	Hetta	49	7	0.67	Sitkoh	na	na	na
Gut Bay	33	1	0.60	Falls	29	1	0.69	Kook	na	na	na
				Gut Bay	24	1	0.61	Gut	na	na	na
Average	245	34	0.76	Average	311	40	0.75	Average	288	23	0.71
Median	217	17	0.73	Median	269	17	0.75	Median	316	7	0.68

Appendix E.–Sockeye fry densities and average weights of age-0 fry in selected Southeast Alaska lakes with important subsistence runs, 2002. Total population estimates of small pelagic fish were based on hydroacoustic surveys of each lake, and sockeye populations were estimated from the proportions of sockeye fry in tow net samples. Fry density estimates are the total sockeye population divided by the estimated surface area for each lake. Average weights of age-0 fry will vary with sample date; in general, the later in the season the lake was sampled the larger the fry.

Lake	Date sampled	Fry·100 m^{-2}	Av. wt. age-0 fry (g)
Hetta	Jul 18	44	0.3
Kutlaku	Aug 9	41	1.1
Gut Bay	Aug 23	25	0.5
Klag	Aug 25	23	1.1
Luck	Jul 22	23	0.4
Hoktaheen	Oct 13	18	1.4
Sitkoh	Aug 13	11	1.1
Klawock I	Jul 17	4	0.6
Kanalku	Aug 10	3	1.0
Klawock II	Oct 2	3	1.8
Falls	Aug 24	2	0.7
Kook	Aug 11	2	0.8
Salmon Bay	Sep 22	2	1.0